Norfolk Boreas Offshore Wind Farm

Proposed Sediment Disposal Site Site Characterisation Report

(Version 3) (Clean)

DCO Document 8.15

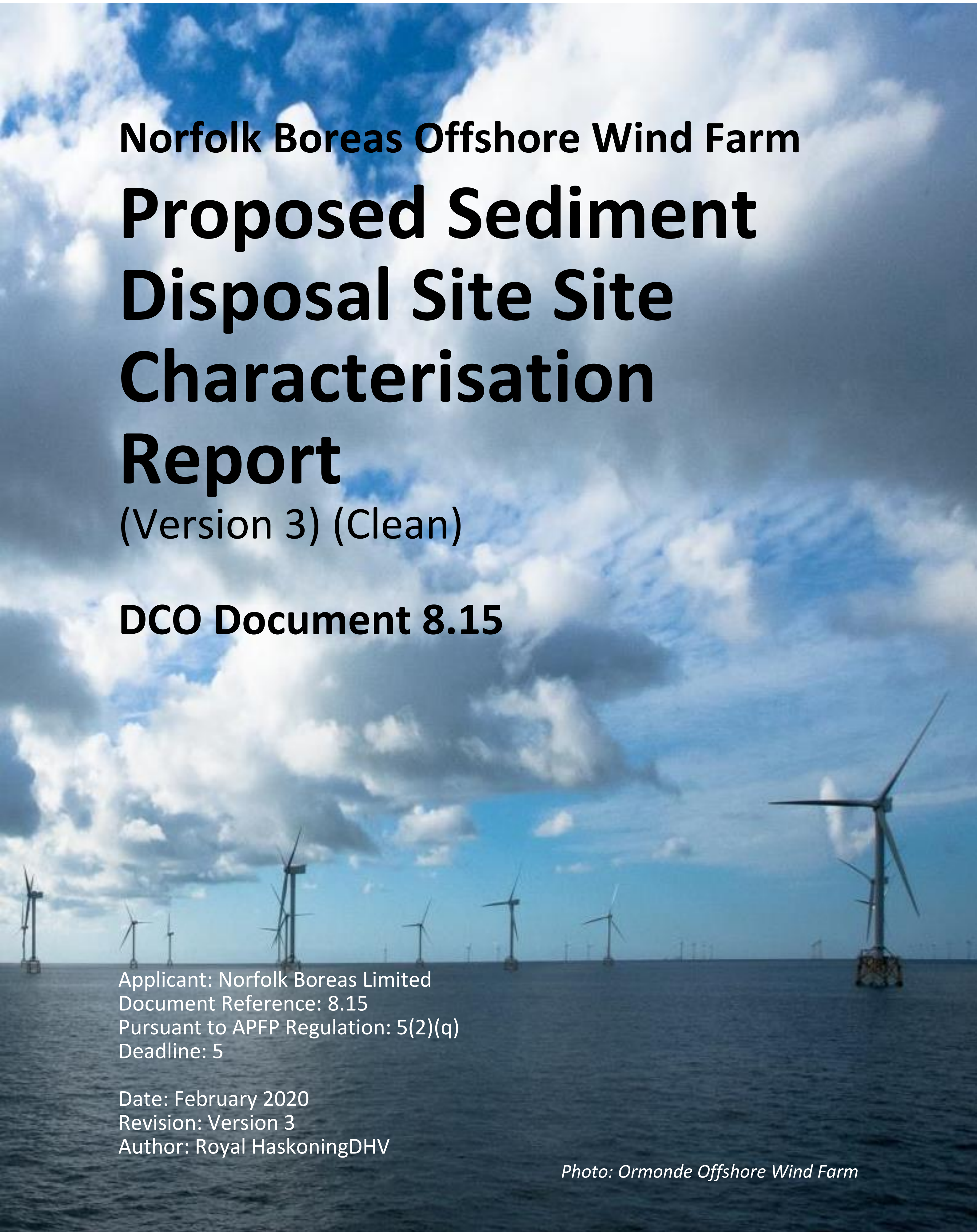

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Photo: Ormonde Offshore Wind Farm

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Glossary of Acronyms

DCO	Development Consent Order
DML	Deemed Marine Licence
ES	Environmental Statement
GBS	Gravity Based Structure
MARSEA	Marine Evidence based Sensitivity Assessment
MMO	Marine Management Organisation
MW	Megawatt
NV East	Norfolk Vanguard East
NV West	Norfolk Vanguard West
OWF	Offshore Wind Farm
PEMP	Project Environmental Information Plan
SAC	Special Area of Conservation

Glossary of Terminology

Array cables	Cables which link wind turbine to wind turbine, and wind turbine to offshore electrical platforms.
Capital dredging	Dredging of an area which has not previously been dredged (see Maintenance Dredging) for a new capital project, e.g. an offshore wind farm, port or harbour.
Interconnector cables	Offshore cables which link offshore electrical platforms within the Norfolk Boreas site.
Landfall	Where the offshore cables come ashore at Happisburgh South
Maintenance dredging	The action of dredging to keep an existing navigation channel open
Norfolk Boreas site	The Norfolk Boreas wind farm boundary. Located offshore, this will contain all the wind farm array.
Norfolk Vanguard East and Norfolk Vanguard West	Two distinct offshore wind farm areas within the Norfolk Vanguard project.
Offshore cable corridor	The corridor of seabed from the Norfolk Boreas site to the landfall site within which the offshore export cables will be located.
Offshore electrical platform	A fixed structure located within the Norfolk Boreas site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a suitable form for export to shore.
Offshore export cables	The cables which transmit power from the offshore electrical platform to the landfall.
Offshore project area	The area including the Norfolk Boreas site, project interconnector search area and offshore cable corridor.
Offshore service platform	A platform to house workers offshore and/or provide helicopter refuelling facilities. An accommodation vessel may be used as an alternative for housing workers.
Pre-sweeping	A discrete dredging operation designed to lower the seabed level within a distinct identified channel to enable marine cables to be installed to a depth

	which reduces the risk of cable exposure and minimises the likelihood of reburial operations.
Proposed Norfolk Boreas disposal site	An area which Norfolk Boreas Limited propose to be designated as a new disposal site. It consists of the boundary of the Norfolk Boreas site and a small section of the offshore cable corridor (see Figure 1.1)
Project interconnector cable	Offshore cables which would link either turbines or an offshore electrical platform in the Norfolk Boreas site with an offshore electrical platform in one of the Norfolk Vanguard OWF sites.
Project interconnector search area	Offshore cables which would link either turbines or an offshore electrical platform in the Norfolk Boreas site with an offshore electrical platform in one of the Norfolk Vanguard sites.
Safety zone	An area around a vessel which should be avoided during offshore construction.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
The Applicant	Norfolk Boreas Limited
The project	Norfolk Boreas Wind Farm including the onshore and offshore infrastructure.

1 INTRODUCTION

1.1 Purpose of this Document

1. Norfolk Boreas Limited is applying to dispose of material in four existing disposal sites and to designate one new disposal site. These sites will be used for disposal of seabed material extracted during the construction of the Norfolk Boreas Offshore Wind Farm (e.g. drilling and / or seabed preparation (dredging)).

2. Norfolk Boreas Limited is seeking to dispose of seabed material in the following four existing disposal sites, also shown in Figure 1.1:

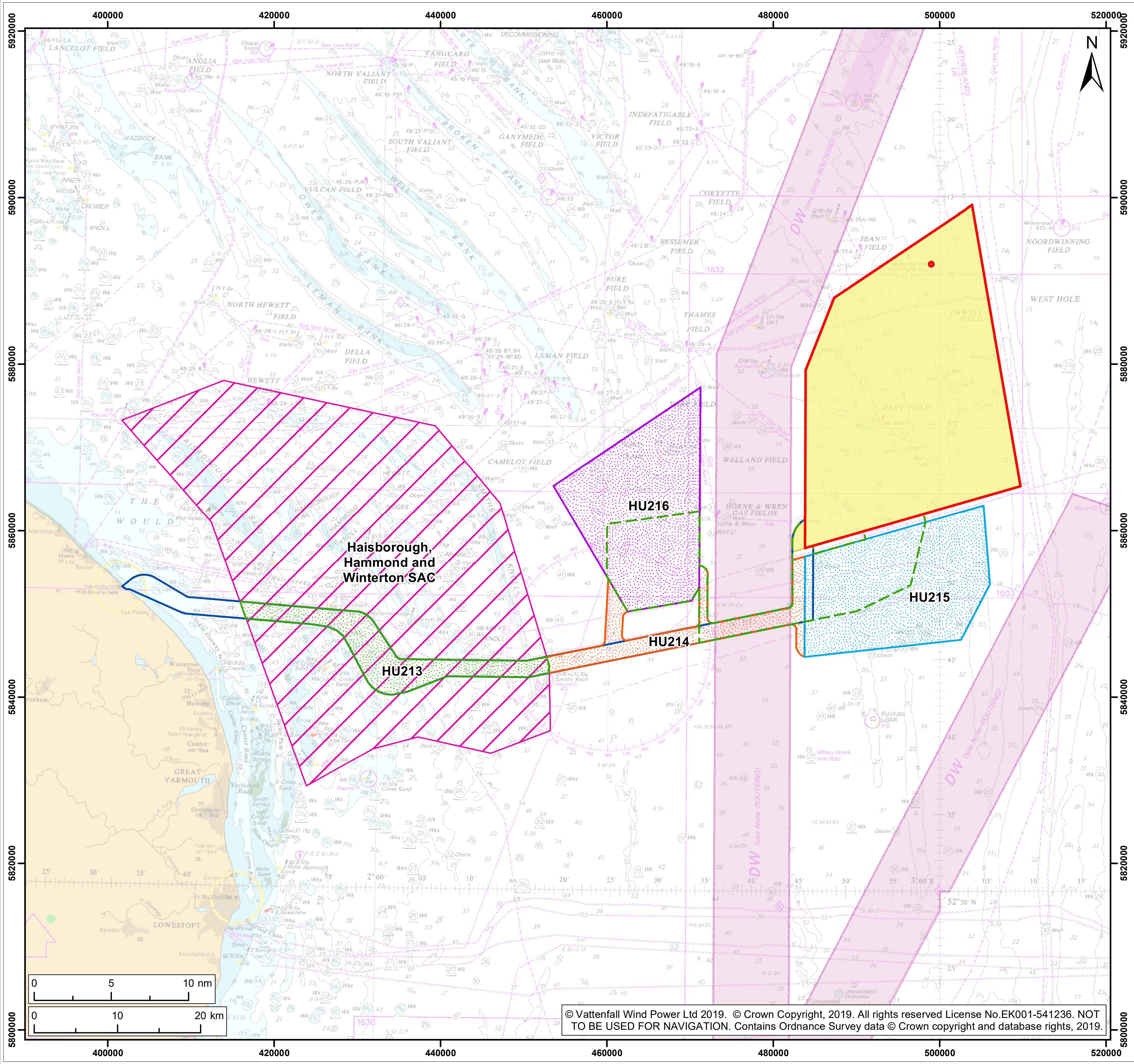
- Site reference HU213;
- Site reference HU214;
- Site reference HU215; and
- Site reference HU216.

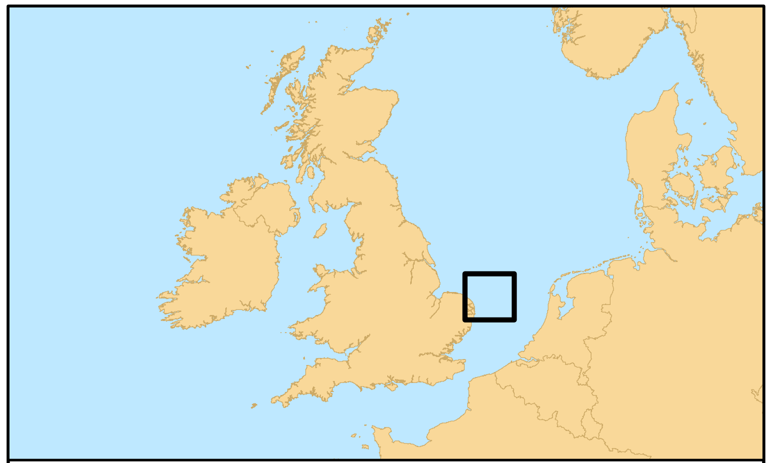
3. In addition, Norfolk Boreas Limited is also seeking to designate a new disposal site, as shown in yellow on Figure 1.1. The coordinates of the new proposed disposal site is provided in Appendix 1 of this report.

4. The purpose of this document is to provide the information required to enable Norfolk Boreas to dispose of material within the existing sites and to enable site designation of the new site. Accordingly, this document sets out:

- The need for disposal of material;
- Alternatives considered;
- The location of the disposal sites;
- The types of material to be disposed of;
- The quantity of the material to be disposed; and
- Potential impacts of disposal.

5. This document was updated in September 2019 and submitted to the MMO. The update was in response to the MMO's advice that the document should be restructured to allow for disposal of sediment within the Norfolk Vanguard disposal sites. The document was updated accordingly and resubmitted to the MMO for the disposal licence application. The document has been updated a second time, for Deadline 5 (26th February 2020) of the Norfolk Boreas examination, to take account of a commitment to reduce the maximum number of turbines within the Norfolk Boreas site to mitigate ornithological impacts (further information can be found in an Offshore Ornithology Assessment Update also submitted at Deadline 5 of the Norfolk Boreas Examination [ExA.AS-8.D5.V2]).





Legend:

- Norfolk Boreas site
- Offshore cable corridor
- Project interconnector search area
- Deep water shipping route
- Special Area of Conservation (SAC)[1]
- Proposed Norfolk Boreas Disposal site

Norfolk Vanguard disposal site[2]

- HU213
- HU214
- HU215
- HU216

[1] JNCC, 2019.
[2] Cefas, 2019.

Project:	Report:
Norfolk Boreas	Site Characterisation Report

Title:

Disposal Sites

Figure: 1.1 Drawing No: PB5640-008-003-001

Revision:	Date:	Drawn:	Checked:	Size:	Scale:
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Co-ordinate system: ETRS 1989 UTM Zone 31N **EPSG:** 25831

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1.2 Background

6. Norfolk Boreas Limited (an affiliate company of Vattenfall Wind Power Limited (VWPL), ‘the Applicant’) is proposing to develop Norfolk Boreas, an offshore wind farm in the southern North Sea.

7. The Norfolk Boreas project comprises the Norfolk Boreas site, within which wind turbines, associated platforms and array cables will be located. The offshore wind farm will be connected to the shore by offshore export cables installed within the offshore cable corridor from the wind farm to a landfall point at Happisburgh South, Norfolk. From there onshore cables would transport power over approximately 60km to the onshore project substation near to the village of Necton, Norfolk. A full project description is given in the Environmental Statement (ES), Chapter 5 Project Description (document reference 6.1.5 of the Application, APP-218).

8. Vattenfall Wind Power Limited (VWPL) (the parent company of Norfolk Boreas Limited) is also developing Norfolk Vanguard, a ‘sister project’ to Norfolk Boreas. The majority of the Norfolk Boreas and Norfolk Vanguard offshore cable corridors (in which the export cables would be installed) overlap. This is illustrated in the Inter-relationship Report (document reference 3.4 of the Application, APP-023). Norfolk Vanguard’s development schedule is approximately one year ahead of Norfolk Boreas and as such the Norfolk Vanguard project has now completed its examination.

9. Norfolk Vanguard may undertake some onshore enabling works for Norfolk Boreas, but these are not relevant to this document. Should Norfolk Vanguard proceed to construction Norfolk Boreas wish to maintain the option to connect to the Norfolk Vanguard project via a “project interconnector”. Further information on why a project interconnector may be required is provided in ES Chapter 5 Project description section 5.4.12.

10. Following an application for a Development Consent Order (DCO) by Norfolk Vanguard Limited the Marine Management Organisation (MMO) has designated four disposal sites. These are shown in Figure 1.1 and are as follows:

- Site reference HU213 which covers the area of the offshore cable corridor that overlaps with the Haisborough Hammond and Winterton SAC;
- Site reference HU214 which covers the parts of the Norfolk Vanguard Offshore cable corridor located outside of the Haisborough Hammond and Winterton SAC;
- Site reference HU215 which covers Norfolk Vanguard East; and
- Site reference HU216 which covers Norfolk Vanguard West.

11. As it is not yet known whether Norfolk Vanguard will obtain development consent (a decision by the secretary of state is expected in December 2019) or proceed to implementation and construction, the Norfolk Boreas application needs to seek consent to implement Norfolk Boreas as an independent project. Therefore, Norfolk Boreas Limited has included two scenarios in the development consent application as follows:

- Scenario 1: Norfolk Vanguard and Norfolk Boreas are both delivered (with associated synergies), and Norfolk Vanguard carries out shared works, onshore to benefit Norfolk Boreas (Scenario 1).
- Scenario 2: Only Norfolk Boreas is delivered; Norfolk Vanguard does not proceed to construction and Norfolk Boreas proceeds alone. Norfolk Boreas undertakes all works required as an independent project (Scenario 2).

12. Both scenarios have been considered when drafting this document. The main difference between the two scenarios would be that under Scenario 1 the project interconnector could be required, which would be installed within the project interconnector search area (Figure 1.1) whereas under Scenario 2 it would not be required as Norfolk Vanguard would not exist and therefore it would not be possible to connect to that project.

13. Under Scenario 1 disposal of material may be required in all four of the existing disposal sites designated by Norfolk Vanguard, however under Scenario 2 (where a project interconnector would not be installed) only disposal within HU213 and HU214 (Figure 1.1) would be required. The MMO have confirmed that should Norfolk Vanguard not proceed to construction, HU213 and HU214 would still be open for disposal of material by Norfolk Boreas.

14. Once built, Norfolk Boreas would have an export capacity of up to 1,800MW, with the offshore components comprising:
    - Wind turbines;
    - Offshore electrical platforms;
    - A service platform;
    - Met masts;
    - Lidar;
    - Array cables;
    - Inter-connector cables or project interconnector cables[1]; and
    - Export cables.

[1] There may be a requirement to place cables within the project interconnector search area (Figure 1.1) which would link the Norfolk Boreas project to the Norfolk Vanguard project (section 5.4.12 of ES Chapter 5 Project Description). Either “Interconnector cables”, which would link platforms within the Norfolk Boreas site, would be installed or “project interconnector cables” would be installed. Under no scenario would both be required.

15. The key onshore components of the project are as follows:

- Landfall;
- Onshore cable route, accesses, trenchless crossing (e.g. Horizontal Directional Drilling (HDD)) zones and mobilisation areas;
- Onshore project substation; and
- Extension to the Necton National Grid substation and overhead line modifications.

16. The Norfolk Boreas site is located approximately 73km from the closest point of the Norfolk Coast. The site covers an area of approximately 725km^2.

17. The detailed design of Norfolk Boreas (e.g. numbers of wind turbines, layout configuration, foundation type and requirement for scour protection) would not be determined until post-consent. Therefore, realistic worst case scenarios in terms of potential impacts/effects are adopted to undertake a precautionary and robust impact assessment.

18. For Norfolk Boreas, several different sizes of wind turbine are being considered in the range of 11.55MW and 20MW. In order to achieve the maximum 1,800MW export capacity, there would be between 90 (20MW) and 158 (11.55MW) wind turbines.

19. In addition, up to two offshore electrical platforms, a service platform, two meteorological masts, two LiDAR platforms and two wave buoys, plus a network of up to 740km of offshore cables are considered as part of the worst-case scenario within the Norfolk Boreas site.

20. Norfolk Boreas Limited is considering constructing the project in either a single phase of up to 1,800MW or in two phases (up to a maximum of 1800MW). The layout of the wind turbines will be defined post consent.

21. The full construction window is expected to be up to three years for the full export 1,800MW capacity and offshore construction would be anticipated to commence around 2025. Chapter 5 Project Description provides indicative construction programmes for the single phase and two phase options. Further detail on construction programme is provided in section 4.3.

2 THE NEED FOR DISPOSAL OF MATERIAL

22. The type of foundation and installation method required for the wind turbines and other offshore structures associated with Norfolk Boreas are yet to be determined. Foundation types currently under consideration include gravity base structures (GBS), monopiles, suction caissons, quadropod or tripod pin-piles (jackets) and Tetrabase foundations.

23. Seabed preparation and potential drilling of pin-piles and monopiles, if required, would result in the production of material which requires disposal. Therefore, practicable options for the disposal of "capital" dredged material must be assessed. Materials arising from drilling would only require disposal within the proposed Norfolk Boreas disposal site.

24. Furthermore, the option of pre-sweeping to a stable reference seabed level may be undertaken to reduce the potential that cables become unburied over the life of the project. Natural England has requested that where pre-sweeping is undertaken within the Haisborough, Hammond and Winterton SAC, any dredged seabed sediment should be disposed of back into the SAC to ensure material is not lost from the system. Further information about how this would be achieved is provided in section 5.4.13 of Chapter 5 Project Description of the Norfolk Boreas ES (document reference 6.1.5 of the Application, APP-218).

2.1 Foundation installation

25. As previously stated there are several possible foundation types currently being considered for the wind turbines. Within these categories there are a number of variants which include:

- GBS – which rely on the weight of the structure to anchor it to the seabed;
- Suction caissons – cylindrical tubes which are installed by reducing the pressure inside the tube to draw the caisson into the seabed;
- Quadropod and tripod - jacket foundations with either three or four feet attached to the seabed with either 3 or 4 suction caissons or piles;
- Monopiles – large cylinders which are hammered into the seabed; and
- TetraBase – installed using either three pin piles or three suction caissons per foundation.

26. The following foundation options are also being considered for the other offshore infrastructure:

- Jacket, GBS or monopile for meteorological mast (met mast) foundations;
- Jacket or GBS for offshore electrical platforms and offshore service platforms;

- Anchored or monopile LiDAR; and
- Anchored buoys.

27. Further information on the foundation types being considered for the project can be found in Chapter 5 Project Description of the Norfolk Boreas ES.

28. Information regarding the maximum predicted amounts of material arising from the installation of foundations is provided in Section 4 of this document. The installation processes associated with the need for sediment disposal are summarised below.

2.1.1 Gravity Base Structures

29. For GBS, it is possible that seabed preparation would be required. This is dependent on the ground conditions present. The preference is that GBS foundations are installed where no or limited ground preparation is required with micro-siting used to minimise any dredging requirements. Assessment of the available geophysical data (Fugro, 2017) indicates that there are areas within the Norfolk Boreas site which if chosen for GBS foundation locations would require seabed preparation. The worst case scenario for GBS therefore assumes an excavation to level of an area of sandwaves up to 5m in depth and 60m diameter for the largest GBS foundations.

2.1.2 Suction Caisson

30. As with GBS, it is possible that seabed preparation will be required for suction caisson foundations. The worst case excavation estimated volumes are predicted to be no worse than for the GBS foundations, as identified above.

2.1.3 Piled jacket foundations

31. For jacket foundations some dredging may be required for levelling the seabed prior to the installation of a pile template (if used). However, it should be possible to spread this material close to the installation works.

32. Based on preliminary geotechnical information from the Norfolk Boreas site (Fugro 2017), it is thought that pile driving would be possible across the whole project site, which will not generate drilled spoil material. However, until more detailed geotechnical assessments are carried out, the possibility of drilling must be considered at some locations. As at the date of this document, Norfolk Boreas has limited information to assess the percentage of drilled piles required.

33. If drilling is required it will generate some spoil material that will require removal and disposal. It is proposed that the spoil will be disposed of within the wind farm area, adjacent to each location from where the material was derived, with the spoil subsequently winnowed away by the natural tide and wave driven processes as described in Chapter 8 Marine Geology, Oceanography and Physical Processes.

2.1.4 Monopiles

34. It is expected that monopiles will be positioned to avoid seabed preparation, however if sand waves are present, the seabed might need to be levelled first by excavation to the trough of the sand wave. The worst case assumption is that excavation to 5m depth is required from an area with a diameter of 15m.

35. If drilling is required it will generate some spoil material that will require removal and disposal. It is proposed the spoil will be disposed of within the wind farm area, adjacent to each location from where the material was derived, with the spoil subsequently winnowed away by the natural tide and wave driven processes.

2.1.5 TetraBase

36. It is unlikely that TetraBase foundations would require significant seabed preparation. However, depending on the ground conditions and anchor type selected (gravity, pin pile or suction bucket), there might be a requirement to carry out some seabed levelling at few locations; this would be to provide a more level area on which to install the foundation. The structure would be able to accommodate inclinations but some dredging may be required to cover areas with steeper slopes. The volume and area impacted by seabed preparation would be significantly less than that of a GBS. Sediment disposal would be as discussed for Jacket foundations in section 2.1.1.

37. In all cases it is proposed that material will be redistributed within the wind farm area and close to the individual foundation locations.

2.2 Cable installation

38. Seabed preparation could be required for installation of all offshore electrical cables including:

- Up to 600km of array cables;
- Up to 250km of export cable trenches (including approximately 50km of export cable trenching within the Norfolk Boreas site);
- Up to 60km of interconnector cable trenches within the Norfolk Boreas site or up to 92km of project interconnector cable trenches within the project interconnector search area[2]; and
- Fibre optic cables may also be installed; however, these would be bundled with the electrical cables and installed within the same trenches.

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[2] This will depend on which electrical solution is chosen (see section 5.4.12 of Chapter 5 Project description of the ES). It should be noted that either “Interconnector cables” would be installed or “project interconnector cables” would be installed. Under no scenario would both be required.

39. Any dredged seabed material would be disposed of within the cable corridor, Norfolk Boreas site or project interconnector cable search area. Material removed from within the Haisborough, Hammond and Winterton SAC which would be disposed of back within the SAC to ensure that this material is not lost from the system.

2.3 Embedded mitigation

40. Norfolk Boreas Limited has committed to a number of areas of embedded mitigation in order to reduce the potential impacts of the project. The following examples of embedded mitigation are of relevance to sediment disposal:

- Reduction of turbine numbers by committing to use larger turbines within the range of 11.55MW to 20MW and thereby reducing the volume of foundation pre-sweeping required.
- Committing to using a High Voltage Direct Current (HVDC) solution in order to reduce the number of export cables and offshore electrical platforms when compared to the High Voltage Alternating Current (HVAC) option. This significantly reduces the volume of pre-sweeping required, particularly in the Haisborough Hammond and Winterton SAC.
- Pre-construction surveys (secured within the relevant Deemed Marine Licences (DMLs) of the DCO (document reference 3.1) and in accordance with the In Principle Monitoring Plan, document reference 8.12) to be undertaken in advance of any cable and foundation installation works. The methodology for the pre-construction surveys would be agreed with the MMO, in consultation with Natural England. The results of this survey would be used to plan the location of wind turbines and the routing of all Norfolk Boreas cables, including micrositing where possible. The locations and cable routes would then be agreed with the MMO and Natural England through agreement of the final Cable Statement (document reference 7.1).
- All seabed material arising from the Haisborough, Hammond and Winterton SAC during cable installation would be placed back into the SAC (existing disposal licence reference HU213, Figure 1.1) using an approach, to be agreed with the MMO in consultation with Natural England, which would ensure that the sediment is available to replenish the sandbank features.
- Sediment would not be disposed of within 50m of confirmed core *Sabellaria Spinulosa* reef in accordance with advice from Natural England.
- Norfolk Boreas Limited have committed to production of a Norfolk Boreas Haisborough Hammond and Winterton SAC Site Integrity Plan (Condition 9 (1)(m) of Schedules 11 and 12 (Transmission DMLs) of the Norfolk Boreas DCO). This document would be the primary mechanism by which the Applicant to agree all works and mitigation associated with cable installation (including

seabed preparation) and maintenance within the Haisborough Hammond and Winterton SAC, with the MMO in consultation with Natural England, in order to ensure there would be no adverse effect on integrity of the site as a result of Norfolk Boreas. An outline of this plan was submitted as part of the Norfolk Boreas DCO application (document reference 8.20 of the Application, APP-711).

3 TYPE OF MATERIAL TO BE DISPOSED

41. As discussed below, materials to be disposed of would be comprised either of seabed and shallow near-bed surface sediments as a result of dredging, or, sub-surface sediments, if drilling is required. Details on the physical characteristics of the seabed and subsurface material across the offshore project area are presented within Chapter 8 Marine Geology, Oceanography and Physical Processes (documents reference 6.1.8 of the Application, APP-221) with the main characteristics summarised within this section.

3.1 Seabed Sediment Type

42. This section describes the surface and subsurface sediment types which may be dredged or drilled as part of Norfolk Boreas construction and would therefore require disposal.

3.1.1 Seabed Surface Sediments

43. Grab samples of surface sediments were collected as part of a comprehensive benthic survey undertaken in 2010 across the former East Anglia Zone and geophysical and grab sampling was undertaken in the former East Anglia FOUR (now Norfolk Vanguard East) in 2012.

44. Project-specific surveys were undertaken for Norfolk Vanguard to supplement the data collected for the former East Anglia FOUR site. A geophysical survey was also completed for Norfolk Vanguard West and the offshore cable corridor between September and November 2016 (Fugro, 2017a). These cover the project interconnector search area and the offshore cable corridor which have been designated as disposal sites HU213, HU214, HU215 and HU216 (Figure 1.1).

45. Geophysical and grab survey samples have also been taken from the Norfolk Boreas site as part of the benthic ecology site characterisation survey (Fugro, 2018). The survey methodology and sampling effort was agreed with Natural England and the MMO. These surveys cover the proposed Norfolk Boreas disposal site.

3.1.1.1 The Norfolk Boreas site

46. The Norfolk Boreas site comprises the majority of the proposed Norfolk Boreas disposal site (Figure 1.1) with the addition of a small section of the offshore cable corridor. A total of 136 seabed sediment samples have been collected in the Norfolk Boreas site. The dominant sediment type is sand (65-100% content in all samples) with median particle sizes mainly between 0.17 and 0.33mm (fine to medium sand). The mud content is less than 5% in 80% of the samples and less than 10% in 90%. However, 10% of the samples contain greater than 10% mud, ranging from 10% to 31%. The gravel content is less than 5% in 90% of the samples.

3.1.1.2 Offshore cable corridor

47. The majority of the Norfolk Boreas offshore cable corridor falls within existing disposal site HU213 and HU214 (Figure 1.1). The only exception is the small section at the eastern end which would be included within the proposed Norfolk Boreas disposal site. A total of 47 seabed samples have been collected along the offshore cable corridor. Sediment distribution is variable depending on location. However, the dominant sediment size is sand. Higher proportions of mud (greater than 10%) were found in 25% of samples with two samples containing greater than 60% mud. Many samples closer to the coast contained greater than 50% gravel.

3.1.1.3 Project Interconnector search area

48. The project interconnector search area occupies the southern half of Norfolk Vanguard West (and its connection to the cable corridor) and the north-west portion of Norfolk Vanguard East, and falls within existing disposal sites HU214, HU215 and HU216 (Figure 1.1). A total of 36 seabed samples fall within the boundary of the project interconnector search area.

49. 18 seabed sediment samples have been collected in the project interconnector search area in the southern half of Norfolk Vanguard West. The dominant sediment type is medium-grained sand with median particle sizes mainly between 0.25 and 0.40mm. The mud content is less than 5% in 83% of the samples. However, 17% of the samples contain greater than 15% mud, ranging from 15% to 45%. The gravel content varies from zero to 9% in all the samples.

50. 18 seabed sediment samples have also been collected in in the project interconnector search area in the north-west part of Norfolk Vanguard East. The dominant sediment type is medium-grained sand (82-100% sand) with median particle sizes between 0.20mm and 0.37mm, with most samples (90%) containing less than 5% mud. The gravel content varies from zero to 7% in all the samples.

3.1.2 Sub-surface sediments

51. Sub-surface sediments within the Norfolk Boreas site are described using data collected during the May – August 2017 surveys conducted by Fugro and reported in Fugro (2018). The offshore cable corridor and project interconnector search area were surveyed in September – November 2016 as reported in Fugro (2016). The Former East Anglia FOUR site (project interconnector search area within NV East) was surveyed in June – September 2012 (Fugro EMU, 2013).

52. The geology of the offshore project area generally consists of Holocene sand deposits overlying a series of Pleistocene sands and clays.

53. The sequence between the Smith's Knoll Formation and the Twente Formation is Pleistocene in age, whereas the Elbow Formation and Bligh Bank Formation are Holocene. The sequence between the Westkapelle Ground Formation and the Twente Formation is Pleistocene in age, whereas the Elbow Formation and Bligh Bank Formation are Holocene. The thickness of the Holocene sediment varies from less than 1m to greater than 20m in the sand wave fields and sand banks.

3.1.2.1 Norfolk Boreas Site and western part of the Project Interconnector Search Area

54. Fugro (2017) described eight geological formations (Table 3.1). The sequence between the Westkapelle Ground Formation and the Twente Formation is Pleistocene in age, whereas the Elbow Formation and Bligh Bank Formation are Holocene.

55. The geology of the Norfolk Boreas site generally consists of Holocene sand deposits overlying a series of Pleistocene sands and clays. The Bligh Bank Formation blankets most of the site with variable thickness. It is thickest beneath the sandbanks (up to 11m) and is a thin seabed veneer (less than 1m) in the bathymetric lows. It represents the sediment currently being reworked into sandbanks, sand waves and megaripples

Table 3.1 Geological formations present under the Norfolk Boreas site and the project interconnector search area in the southern half of NV West* (Fugro, 2016; Fugro, 2017a).

Formation	Norfolk Boreas	Project interconnector search area in Norfolk Vanguard West	Lithology (BGS Lexicon http://www.bgs.ac.uk/lexicon)
Bligh Bank	Present	Present	Marine, medium- or fine- to medium-grained, clean, yellow-brown sands
Elbow	Present	Present	Brackish-marine, fine-grained sands and clays with discontinuous basal peat bed
Twente	Present	Present	Fine-grained, well-sorted, wind-blown periglacial sands
Brown Bank	Present	Present	Brackish-marine, grey-brown silty clays. Pass upwards into lacustrine clays in the east, include interbeds gravelly sand towards base in west
Swarte Bank	Present	Present	Infilled glacial tunnel valleys
Yarmouth Roads	Present	Present	Mainly riverine, fine or medium-grained grey-green sands, typically non-calcareous, with variable clay lamination and local intercalations of reworked peat
Winterton Shoal	Present	Present	Fine- or medium-grained sands with minor clay laminations
Smith's Knoll	Thought to be present but not resolved in the Norfolk Boreas site surveys	Present	Fine to medium-grained, muddy marine sands, with clay intercalations in the east

Formation	Norfolk Boreas	Project interconnector search area in Norfolk Vanguard West	Lithology (BGS Lexicon http://www.bgs.ac.uk/lexicon)
Westkapelle Ground	Not reached or absent	Present	Marine clays with thin sandy laminae passing gradationally upwards to sand with thin clay laminae

3.1.2.2 Offshore cable corridor

56. Fugro (2017a) completed the offshore cable corridor geophysical survey in 2016 using three different survey vessels. This was due to vessel operation limitations with regards to minimum water depths, and so the corridor was split into three sub-sections (west, central and east). The sub-sections were surveyed using a pinger sub-bottom profiler, achieving a typical penetration of about 15m below seabed in the eastern sub-section, whereas the western and central sub-sections achieved 5m penetration. Differences in ground conditions along each section resulted in different attenuations of the seismic signal using the same pinger.

57. Pinger sub-bottom profiler penetration can be limited by subsurface sediment type and structure. Also, if the geological units are homogenous, or have little structure, the pinger will be unable to resolve different formations. Hence, within the western and central sub-sections (5m penetration), the shallow geological sequence is only divided into Holocene sands and the underlying undifferentiated Pleistocene sediments. Along the eastern sub-section, Fugro (2017a) described the Pleistocene Yarmouth Roads Formation overlain in sequence by the Pleistocene Eem Formation (fine- to medium-grained shelly marine sands and not present beneath the Norfolk Boreas site), Brown Bank Formation and Twente Formation, and then Holocene formations to the seabed.

3.1.2.3 Eastern part of the Project Interconnector Search Area

58. The Norfolk Vanguard survey (Fugro, 2016) described nine geological formations that are beneath the project interconnector search area in the southern half of Norfolk Vanguard West (the same as Norfolk Boreas but including the older Westkapelle Formation. The Bligh Bank Formation is present across most of the project interconnector search area.

59. Fugro EMU (2013) described three geological formations that are within the project interconnector search area in the north-west part of Norfolk Vanguard East. In ascending order, these are the Pleistocene Yarmouth Roads Formation comprising 0m to 100m of sands and channel infills, overlain by the Pleistocene Brown Bank Formation comprising 5m to 10m of silty clay, capped by 0m to 20m of Bligh Bank Formation (Holocene sand). The Holocene sand varies in thickness from several metres beneath sandbanks and sand waves to a thinner veneer in deeper areas.

60. The base of the Yarmouth Roads Formation was not imaged by the sub-bottom profiler, and so the older formations described at the project interconnector search area in the southern half of Norfolk Vanguard West (Fugro, 2016) were not delineated across the project interconnector search area in the north-west part of Norfolk Vanguard East.

3.2 Sediment Contamination Analysis

61. Alongside defining the biological and physical characteristics of the Norfolk Boreas offshore project area, benthic and contaminant surveys were undertaken in August 2017 across the Norfolk Boreas site. This survey aimed to characterise the physical, biological and chemical nature of the seabed. As Norfolk Boreas shares the majority of its offshore cable corridor with Norfolk Vanguard it was agreed through the Evidence Plan Process (EPP) with the regulators (see Chapter 7 Technical consultation of the ES for further detail on the EPP), that the Norfolk Vanguard survey would be used to inform the EIA for Norfolk Boreas.

62. As part of the Norfolk Boreas site survey, sediment grab samples were obtained from 35 locations within the site. Of the 35 samples collected, eight were selected for contaminant analysis on the basis of the percentage of fine material present (as requested by the MMO) and two were selected to ensure even coverage across the site.

63. Table 3.2 provides reference to the sample numbers which are located within the proposed disposal site area and their respective locations. A spatial representation is provided in Chapter 9, Figure 9.2 of the Norfolk Boreas ES (document reference 9.2.9.2 of the Application, APP-289).

Table 3.2 Contaminant samples and their associated location

Location	Sample Number
Norfolk Boreas site (proposed Norfolk Boreas disposal site)	ST03, ST05, ST10, ST14, ST16, ST22, ST23, ST30, ST31, ST35ST
Project interconnector search area (within HU214, HU215 and HU216)	16MS, 03MS
Offshore cable corridor (within HU213 and HU214)	38_CR, 41_CR, 45_CR, 48_CR 56 CR

64. Sediment contaminant data is summarised in Table 3.3. Data highlighted in yellow indicates concentrations of contaminants over Cefas Action Level 1 (Cefas, undated) (there are no concentrations greater than Cefas Action Level 2). All organotin and PCB results were below the limits of detection (0.004 mg/kg and 0.0001 mg/kg respectively) and therefore have not been included in the table.

65. The data summarised in Table 3.3 illustrates that sediment contamination within the offshore cable corridor, project interconnector search area and the Norfolk Boreas site

is low. Only four sites exceeded Cefas Action Level 1 and this was just for concentrations of arsenic at ST03, ST14, 03_MS and 56_CR (highlighted in Table 3.3). These exceedances are marginal as they are only just over the Action Level 1 concentration. The elevated levels of arsenic which were recorded are typical of the region; in the offshore environment these are associated with estuarine and geological inputs and sea bed rock weathering.

66. Since these results indicate low levels of contamination across the site and are in line with samples from other relevant projects, analysis of the reserved stored samples was considered unnecessary. This was agreed with the MMO, Natural England and Cefas, through consultation in October and November 2017 (see section 9.3 of Chapter 9 Marine Water and Sediment Quality of the ES (document reference 6.1.9 of the Application, APP-222) for further detail).

Table 3.3 Sediment contamination analysis results compared to Cefas Action Levels.

Contaminant (mg/kg)	Sample site in Norfolk Boreas site										Offshore cable corridor							Project interconnector search area		
	ST31	ST03	ST10	ST14	ST23	ST30	ST16	ST05	ST35	ST22	24_CR	48_CR	45_CR	56_CR	38_CR	26_CR	41_CR	03_MS	05_MS	16_MS
Arsenic	13.3	21	12	32.7	14.9	10.5	9.4	12.9	8.76	14.4	12.6	11.9	9.75	35.2	10	5.39	11.4	20.4	16.7	10.7
Cadmium	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chromium	12.2	10	7.43	13.9	12.9	7.81	14.5	15.6	14.3	11	3.8	12.8	9.1	4	2.2	4.8	<2	5.3	7.8	11.6
Copper	1.75	1.19	1.14	1.81	1.35	1.06	3.17	3.08	1.38	1.7	1.66	3.35	1.78	<1	<1	<1	<1	1.45	<1	1.95
Nickel	5.4	4.41	4.57	6.41	5.22	4.2	6.95	7.85	5.49	6.1	3.5	6.7	4.4	2.8	1.3	2.25	1.26	3.4	3.5	5.5
Mercury	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.0108	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Lead	4.39	7.17	4.67	9.91	5.09	4.63	6.62	6.74	4.61	4.87	7.16	8.36	4.75	6.36	<2	3.59	2.34	5.12	5.96	5.69
Zinc	15.2	22.3	17.3	27	18.3	16.1	23.7	22.6	14.8	14.7	8.3	22.6	14.4	14.2	5.8	9.9	5.5	12	13.3	18.6
Acenaphthene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.001	0.00101	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Acenaphthylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Anthracene	<1	<1	<1	<1	<1	<1	<1	2.02	<1	<1	<0.001	0.00129	0.00111	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo(a)anthracene	<1	<1	<1	<1	<1	<1	2.11	3.82	<1	<1	<0.001	0.00415	0.00392	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00429
Benzo(a)pyrene	<1	<1	<1	<1	<1	<1	2.54	3.96	<1	<1	<0.001	0.00558	0.00392	<0.001	<0.001	0.00142	<0.001	0.00152	<0.001	0.00543
Benzo(b)fluoranthene	<1	<1	<1	<1	1.56	<1	4.07	5.04	<1	<1	<0.001	0.00759	0.00695	<0.001	<0.001	0.0015	<0.001	0.00234	<0.001	0.0074
Benzo(e) pyrene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<0.005	0.00703	0.0058	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.00605
Benzo(ghi)perylene	<1	<1	<1	<1	1.29	<1	3.78	4.13	<1	<1	<0.001	0.0068	0.00514	<0.001	<0.001	0.00111	<0.001	0.00187	<0.001	0.00526
Benzo(j)fluoranthene	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo(k)fluoranthene	<1	<1	<1	<1	<1	<1	1.85	2.49	<1	<1	<0.001	0.00319	0.0030	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00341
Chrysene + Triphenylene	<3	<3	<3	<3	<3	<3	3.16	4.52	<3	<3	<0.003	0.00629	0.00618	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.00579
Chrysene	<3	<3	<3	<3	<3	<3	<3	3.55	<3	<3	<0.003	0.00432	0.00434	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.00418
Dibenzo(ah)anthracene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dibenzothiophene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fluoranthene	<1	<1	<1	<1	1.55	<1	4.26	9.01	<1	<1	<0.001	0.00809	0.00879	<0.001	<0.001	0.00231	<0.001	0.00186	<0.001	0.00933
Fluorene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Indeno(1,2,3-c,d)pyrene	<1	<1	<1	<1	<1	<1	2.39	3.15	<1	<1	<0.001	0.00528	0.00452	<0.001	<0.001	0.00102	<0.001	0.0015	<0.001	0.00491
Naphthalene	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<0.005	0.00616	0.00599	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Perylene	<5	<5	<5	<5	<5	<5	<5	7.88	<5	<5	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Phenanthrene	<5	<5	<5	<5	<5	<5	6.03	6.62	<5	<5	<0.005	0.00958	0.00953	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.00845
Pyrene	<1	<1	<1	<1	1.3	<1	3.84	7.71	<1	<1	<0.001	0.00699	0.00739	<0.001	<0.001	0.00230	<0.001	0.00160	<0.001	0.00779
Triphenylene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Hydrocarbons: Total	4.29	2.35	6.97	4.63	10.8	2.31	23.7	16	3.53	1.96	5.51	47 3	33.1	<0.9	<0.9	5.02	<0.9	10	3.06	26.2

4 QUANTITY OF MATERIAL TO BE DISPOSED

67. Material to be disposed may arise from the following sources:

- Seabed preparation for foundations (also known as seabed levelling);
- Drill arising when installing foundations; and
- Pre-sweeping for cable installation.

68. Taking a precautionary approach, it has been estimated that a maximum of 50% of the foundation locations within the Norfolk Boreas site would require drilling. Drill arisings would fall rapidly to the seabed in the vicinity of the activity and would not be brought to the surface for disposal.

69. As discussed in section 1.1, Norfolk Boreas could be installed in a single or two phased approach. The spatial requirements for a single or two phased approach are the same and therefore the volume of sediment arising would be the same regardless of the build out scenario. However, the construction programme would vary, and this is outlined in section 4.3 of this document.

4.1 Seabed Preparation

70. Table 4.1 shows the volumes associated with seabed preparation for foundation and cable installation within the proposed disposal sites. The maximum sediment removal during foundation installation would be GBS foundations, any other foundation options would result in less material.

71. The maximum sediment disturbance in relation to seabed levelling for offshore export cable installation would be in relation to a trench length of 250km. This is based on four HVDC cables in two trenches to the wind farm site with a maximum length of 125km from landfall to the offshore electrical platforms.

72. Cable installation will require preparation of the offshore export cable corridor (pre-sweeping by dredging) excluding the nearshore within the 10m water depth contour as Norfolk Boreas Limited has committed to no seabed preparation in this area. These activities are outlined in Table 4.1. Subsequent trenching (e.g. by jetting or ploughing) will then be required to bury the cables. This sediment would not be affected and would therefore not require disposal. The impacts associated with trenching are assessed in the ES (document reference 6.1; Chapters 8, 9, 10, 11 and 12 of the Application, APP-221 to APP225).

73. It should be noted that under Scenario 2 the “Total volume to be disposed of in the project interconnector search area” shown in Table 4.1 would not be required.

Table 4.1 Total disturbance/preparation footprints during construction assessed within the EIA.

Infrastructure	Worst Case Scenario type	Worst Case Scenario volume (m^3)	Disposal Area
Seabed preparation – turbines	158 x 11.55MW turbines on GBS foundations	1,648,824	
Seabed preparation – offshore electrical platforms	Based on two 100m x 75m platforms	75,000	
Seabed preparation - met masts	Based on 40m diameter – 1,257m^2 x 2 met masts	12,566	
Seabed preparation – offshore service platform	Based on one 100m x 75m platforms	37,500	
Array cable pre-sweeping	Based on 20m width x 600,000m length x 3 depth	36,000,000	
Interconnector pre-sweeping	Based on 20m width x 60,000m* length x 3 depth	3,600,000*	
Export cable pre-sweeping within Norfolk Boreas site	Based on 20m width x 50,000m length x 3 depth	3,000,000**	
Total volume to be deposited in Norfolk Boreas site	1,773,890m^3 foundation pre-sweeping; and 42,600,000m^3 Cable pre-sweeping and trenching	**44,373,800**	Proposed Norfolk Boreas disposal site
Export cable pre-sweeping within the offshore cable corridor overlap with the SAC	Based on 2 cable trenches and a study presented in Appendix 5.2 of the ES (document reference 6.3.5, APP-458)	500,000	Existing site HU213
Export cable pre-sweeping within the offshore cable corridor which does not overlap with the SAC	Based on 2 cable trenches and a study presented in Appendix 5.2 of the ES (document reference 6.3.5, APP-458)	100,000	Existing site HU214
Total volume to be disposed of in the offshore cable corridor		**600,000**	
Total volume to be disposed of in the project interconnector search area	Based on up to 10 trenches at 20m width x 92,000m length x 3m depth	**5,520,000*** **	Existing disposal sites HU214, HU215 and HU216 (see Table 4.2 for further detail)

* This would also be the maximum worst case scenario for the sections of the project interconnector cables located within the Norfolk Boreas site, however as either the project interconnector cable or interconnector cables would be installed but never both this value is only included once.

** 4,500,000m^3 of material being 'disturbed' has been assessed within the EIA (see Table 10.12 in Chapter 10 of the ES (document reference 6.1.10 of the Application, APP-223)). 3,000,000m^3 would be as a result of pre-sweeping and 1,500,000m^3 as a direct result of the cable installation process. This is due to the fact that some of the material disturbed due to the act of cable installation could be bought into suspension. However, this material would not be dredged from the seabed and would not require disposal. Therefore 1,500,000m^3 of the total 4,500,000m^3 does not form part of the disposal site application volumes.

*** As the decision on which electrical solution to be installed (see section 5.4.12 of chapter 5 of the ES (document reference 6.1.5 of the Application, APP-218) will not be taken until post consent it is currently not known where this material would be disposed. The worst case scenario would only occur if electrical solution (b) were to be installed (see As referenced in section 1.2 and shown in Figure 1.1, the Norfolk Boreas project interconnector search area overlaps with the three existing disposal sites HU214, HU215 and HU216.Table 4.2 provides the maximum amount of material that could be disposed of within these sites by the Applicant under the worst case scenario for that site. Further information on the different electrical solutions can be found in section 5.4.12 of Chapter 5 Project description of the Norfolk Boreas ES (document reference 6.1.5 of the Application APP-218). It should be noted that only one electrical solution would be installed and therefore the maximum volumes provided in the table are independent from each other and cannot be used to calculate an overall maximum volume.

74. In terms of the disposal of dredged material, the sediment dredged from within the Haisborough, Hammond and Winterton SAC will be disposed of within HU213 to ensure that the sediment remains within the SAC, all other dredged material will be disposed of at a suitable location within HU214, HU216, HU216 and the proposed Norfolk Boreas disposal site.

75. Due to the fact that the EIA takes a geographical approach to assessing impacts and the DCO secures maximum parameters through conditions based on specific infrastructure, the values for parameters such as the maximum quantities of disposal of material are not easily cross referenced between the DCO and the EIA. The EIA and DCO Reconciliation Document (document reference 6.7 of the Application, APP-689) explains how these values can be reconciled. Table 3.6 of the reconciliation document explains that the DCO limits the disposal to a total of 48,537,890m^3 (or 44,973,890m^3 under Scenario 2 where the project interconnector cable could not be installed) whereas the EIA has assessed a maximum disposal of 55,112,212m^3.

Table 4.1 presents the disposal volumes which have been assessed within the EIA, whereas the maximum amount of material to be disposed is secured through Schedule 1, Part 1, Paragraph 1 (c) of the DCO (document reference 3.1 of the Application, APP-020).

76. As referenced in section 1.2 and shown in Figure 1.1, the Norfolk Boreas project interconnector search area overlaps with the three existing disposal sites HU214, HU215 and HU216.Table 4.2 provides the maximum amount of material that could be disposed of within these sites by the Applicant under the worst case scenario for that site. Further information on the different electrical solutions can be found in section 5.4.12 of Chapter 5 Project description of the Norfolk Boreas ES (document reference 6.1.5 of the Application APP-218). It should be noted that only one electrical solution would be installed and therefore the maximum volumes provided in the table are independent from each other and cannot be used to calculate an overall maximum volume.

77. Table 4.2 maximum volume of material that could be disposed of in existing disposal sites as a result of project interconnector cable installation.

Existing disposal site	Maximum Volume of Material (m3)	Electrical solution	Rational
HU214	3,600,000	(c)	Under Solution (c) the maximum length of cable trenching within the offshore cable corridor (and therefore HU214) due to project interconnector cable installation is 60,000m. The width of pre-sweeping would be up to 20m and the average depth of pre-sweeping has been calculated as 3m.
HU215	5,520,000	(b)	Under Electrical solution (b) all of the project interconnector cables would be located within Norfolk Vanguard East and the gap between Norfolk Boreas and Norfolk Vanguard East. This would include 12 km of cables crossing the gap, 8km per cable from the gap to the offshore electrical platform located in NV East of which there would be 10 trenches (8 array cables, 1 AC cable and 1 pair of DC cables in the same trench). Therefore, a total length of 92,000m of trench. The width of pre-sweeping would be up to 20m and the average depth of pre-sweeping has been calculated as 3m.
HU216	1,200,000	(c)	Under Solution (c) the maximum length of cable trenching within Norfolk Vanguard West due to project interconnector cable installation would be 20,000m length. The width of pre-sweeping would be up to 20m and the average depth of pre-sweeping has been calculated as 3m.

78. If electrical solution (b) is taken forward this would represent the worst case scenario in terms of the overall maximum amount of sediment that would require

disposal within the project interconnector search area. Under this electrical solution all 5,520,000m^3 would be disposed of within HU215.

79. If electrical solution (c) were to be taken forward a maximum of 3,600,000m^3 would require disposal within HU214 and a maximum of 1,200,000m^3 would require disposal within HU216.

80. It should be noted that as a result of pre-sweeping for the export cable 100,000m^3 (Table 4.1) would also require disposal in HU214.

4.2 Drilling

81. Table 4.3 shows the volumes associated with drilling for foundation installation within the Norfolk Boreas Site. The maximum sediment arising during foundation drilling would be from monopile turbine foundations, as well as accommodation platforms and offshore electrical platforms on six-legged foundations and met masts on quadropods.

Table 4.3 Maximum drill arisings during construction

Infrastructure	Worst Case Scenario type	Worst Case Scenario volume (m^3)
Turbines	45 (50%) x 20MW turbines on monopiles	397,608
Offshore electrical platforms	2 x six-legged platforms with 18 pin pile	14,137
Offshore service platform	1 x six-legged platforms	848
Met masts	2 x quadropods	1,131
Lidar	2 x monopile	189
Total		**413,913**

4.3 Programme

82. The full construction window is expected to be up to approximately three years for the full 1,800MW export capacity. Table 4.4 and Table 4.5 provide indicative construction programmes for the single phase and two phase options, respectively.

Table 4.4: Indicative Norfolk Boreas construction programme – single phase

Indicative Programme	Approximate duration	2024				2025				2026				2027				2028			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pre-construction survey	12 months																				
UXO survey and licensing	12 months																				
UXO clearance following licencing	9 months																				
Foundation seabed preparation	3 months																				
Foundation installation	18 months																				
Scour protection installation	12 months																				
Offshore Electrical Platform Installation Works	12 months																				
Array & interconnector cable seabed preparation	6 months																				
Array & interconnector cable installation	18 months																				
Export cable installation seabed preparation	6 months																				
Export cable installation	18 months																				
Cable protection installation	18 months																				
Wind turbine installation	18 months																				
Total construction works	36 months																				

Table 4.5: Indicative Norfolk Boreas construction programme – two phase

		2024				2025				2026				2027				2028			
Indicative Programme	**Approximate duration**	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pre-construction survey	12 months				■	■	■														
UXO survey and licensing	12 months				■	■	■														
UXO clearance following licencing	9 months							■	■	■											
Foundation seabed preparation	3 months									■											
Foundation installation	2 x 9 months										■	■	■		■	■	■				
Scour protection installation	2 x 6 months									■	■			■	■						
Offshore Electrical Platform Installation Works	2 x 6 months										■	■			■	■					
Array & interconnector cable seabed preparation	2 x 3 months									■				■							
Array & interconnector cable installation	2 x 9 months										■	■	■		■	■	■				
Export cable installation seabed preparation	2 x 3 months								■				■								
Export cable installation	2 x 9 months									■	■	■		■	■	■					
Cable protection installation	2 x 9 months										■	■	■		■	■	■				
Wind turbine installation	18 months														■	■	■		■	■	■
Total construction works	39 months								■	■	■	■	■	■	■	■	■	■	■	■	■

4.4 Daily Disposal Amounts

83. It is anticipated that approximately 50,000m^3 of daily sediment disposal may be required based on 3 to 4 dredge and disposal activities per day for foundation seabed preparation and/or cable pre-sweeping.

84. It is anticipated that construction of the turbine foundations would either be over an 18 month period under a single phase approach or two nine month periods under the phased approach. Seabed preparation would be a small proportion of this programme and therefore it can be expected that the daily disposal rate quoted above would only occur for limited and discrete periods within the construction phase.

5 ALTERNATIVES CONSIDERED

5.1 Use of Material for Ballast

85. Where extensive excavation works are required, such as for seabed preparation for foundation installation, it is possible that material could be retained and used for infill works or ballast material, if geotechnically suitable for purpose. Ballast material is heavy material which is used to enhance stability of foundations and is likely to be composed of locally dredged sand.

86. As described above, Norfolk Boreas Limited is considering the use of several different foundation types. Sand dredged locally during the seabed preparation could be used as ballast material for GBS foundations during the foundation preparation works if geotechnically suitable for purpose (ballast material is likely to be composed of locally dredged sand). The remainder would be disposed of as described in section 4 above.

87. The use of excavated material as ballast would depend on a suitable foundation type being used and the results of detailed post-consent geotechnical investigations. However, for the purposes of the EIA, and as a worst case for this report, it has been assumed that all drilled and dredged material would be disposed of on site, rather than being used as ballast material.

5.2 Other Disposal Sites

88. In addition to the four disposal sites (HU213, HU214, HU215 and HU216) that Norfolk Boreas Limited propose to use for disposal of material arising from the Norfolk Boreas project, other disposal sites have been considered.

89. Through consultation with Natural England during the Norfolk Vanguard EPP it was identified that it is preferable to dispose of dredged sediment as close to the source as possible, in particular in the Haisborough Hammond and Winterton SAC, in order to minimise potential disturbance impacts.

90. However, the suitability and capacity of other existing disposal sites within a 50km radius of the Norfolk Boreas offshore project area has also been considered (Table 5.1).

Table 5.1 Other existing Disposal Sites within 60km of the Norfolk Boreas offshore project area

Site Name	Site ID	Area km^2	Distance from Norfolk Boreas offshore project area (km)
East Anglia THREE	HU212	935	13.0
East Anglia ONE	TH023	129.4	56.4
Great Yarmouth	HU150	0.67	19.0
Cross Sands 2	HU176	0.30	21.5
Burgh Castle Yacht Station	HU208	0.015	23.8

Site Name	Site ID	Area km^2	Distance from Norfolk Boreas offshore project area (km)
Reedham Marina	HU159	0.001	26.7
Lowestoft Circular North	TH005	0.431	29.4
Lowestoft Marina Temporary Disposal Site	TH011	<0.001	31.5
Wells Outer Harbour B1	HU157	0.02	49.3
Well Beneficial use site2	HU156	0.57	49.3
Wells outer harbour site C	HU154	0.002	49.3
Wells outer harbour site A	HU152	0.006	49.4
Galloper Offshore wind farm	TH057	219.0	59.4

91. The largest sites within 50km of Norfolk Boreas (excluding the sites HU213, HU214, HU215 and HU216) are East Anglia ONE (TH023) and Galloper offshore wind farm (TH057). None of the other disposal sites listed in Table 5.1 are considered large enough to accommodate worst case scenario of up to 48,573,890m^3 of sediment that could require disposal as a result of the construction of the Norfolk Boreas project.

92. The East Anglia ONE, East Anglia THREE and Galloper Offshore wind farm disposal sites have been designated specifically to receive material from within those wind farms and would therefore be less suitable than HU213, HU214, HU215 and HU216 for receiving any material from Norfolk Boreas.

6 POTENTIAL IMPACTS OF DISPOSAL

93. The impact of disposal of material within the Norfolk Boreas site, project interconnector search area and offshore cable corridor has been assessed as part of the Norfolk Boreas EIA and is presented within the ES; specifically within Chapter 8 Marine Geology, Oceanography and Physical Processes (document reference 6.1.8 of the Application, APP-221), Chapter 9 Marine Water and Sediment Quality (document reference 6.1.9 of the Application, APP-222) and Chapter 10 Benthic and Intertidal Ecology (document reference 6.1.10 of the Application, APP-223). It should be noted however, that the ES assesses the impacts of the project as a whole and so the specific parts of the assessment that consider disposal of sediment have been drawn out and are presented below.

94. Chapters 8, 9 and 10 of the Norfolk Boreas ES also contain Cumulative Impact Assessments (CIA) (sections 8.10, 9.10 and 10.10 respectively). Within these assessments cumulative impacts associated with sediment disposal from both the Norfolk Vanguard and Norfolk Boreas projects are assessed (further detail is provided in section 6.4 of this report). This is particularly relevant as Norfolk Boreas is applying to dispose of sediment within disposal sites which have been designated for the Norfolk Vanguard project (section 1.2 of this report).

95. The assessment methodology for sediment and seabed changes associated with the installation of foundations, array cables and the export cables is provided in Chapter 8 Marine Geology, Oceanography and Physical Processes.

96. The assessment of significance has been based on the following;

- Tolerance to an effect (i.e. the extent to which the receptor is adversely affected by a particular effect);
- Adaptability (i.e. the ability of the receptor to avoid adverse impacts that would otherwise arise from a particular effect); and
- Recoverability (i.e. a measure of a receptor's ability to return to a state at, or close to, that which existed before the effect caused a change).

97. The sensitivity and value of discrete morphological receptors have been assessed using expert judgement and described with a standard semantic scale. Definitions are provided in Chapter 8 Marine Geology, Oceanography and Physical Processes.

98. The magnitude of effect is dependent upon its;

- Scale (i.e. size, extent or intensity);
- Duration;
- Frequency of occurrence; and

- Reversibility (i.e. the capability of the environment to return to a condition equivalent to the baseline after the effect ceases).

99. The magnitude of effect has been assessed using expert judgement and described with a standard semantic scale. Definitions for each term are provided in Chapter 8 Marine Geology, Oceanography and Physical Processes.

100. Within Chapter 8 Marine Geology, Oceanography and Physical Processes of the ES, impacts on the physical characteristics of the site have been assessed. The impacts which contain relevant information for this assessment are as follows:

- Changes in suspended sediment concentrations due to seabed preparation for wind turbine foundation installation;
- Changes in suspended sediment concentrations due to drill arisings for installation of piled foundations for wind turbines;
- Changes in seabed level due to seabed preparation for wind turbine foundation installation;
- Changes in seabed level due to drill arisings for installation of piled foundations for wind turbines;
- Changes in suspended sediment concentrations during cable installation within the offshore cable corridor;
- Changes in seabed level due to disposal of sediment from pre-sweeping (sand wave levelling) in the offshore cable corridor;
- Changes in seabed level due to cable installation within the offshore cable corridor;
- Changes in suspended sediment concentrations during cable installation within the Norfolk Boreas site and project interconnector search area; and
- Changes in seabed level due to cable installation within the Norfolk Boreas site and project interconnector search area.

101. Chapter 9 Marine Water and Sediment Quality of the ES incorporates the potential effects of disposal on water and sediment quality. This assessment directly builds upon the assessment in Chapter 8 Marine Geology, Oceanography and Physical Processes. The impacts which contain relevant information for this assessment are as follows:

- Deterioration in offshore water quality due to increased suspended sediment concentrations created by seabed preparation during foundation installation;
- Deterioration in offshore water quality due to increased suspended sediment concentrations due to drill arisings for installation of piled foundations. s;
- Deterioration in water quality due to increased suspended sediment concentrations during installation of cables within the offshore cable corridor;
- Deterioration in offshore water quality due to increased suspended sediment concentrations during cable installation within the Norfolk Boreas site and Project interconnector search area.; and
- Deterioration in water quality (offshore and nearshore) due to re-suspension of sediment bound contaminants.

102. In the ES, Chapter 10 Benthic and Intertidal Ecology incorporates the potential effects of disposal on the biological characteristics of the project. This assessment also builds upon the assessment in Chapter 8 Marine Geology, Oceanography and Physical Processes. The impacts which contain relevant information for this assessment are as follows:

- Temporary habitat loss / disturbance;
- Temporary increase in suspended sediment concentrations and associated sediment disposal; and
- Changes to water quality due to re-mobilisation of contaminated sediments.

103. The impact assessments presented in the ES discuss the impacts of constructing Norfolk Boreas in one or two phases. The results indicate that there is no material difference in the impacts on marine physical processes, water and sediment quality, or benthic ecology for either phasing option, and therefore phasing is not discussed further in this report.

6.1 Norfolk Boreas Site (proposed Norfolk Boreas disposal site)

6.1.1 Potential Impacts of Sediment Disposal on Physical Characteristics in the Norfolk Boreas Site

104. As discussed in section 1.2 The Norfolk Boreas site shown in Figure 1.1 is the area Norfolk Boreas Limited wish to designate as a new disposal site. The following infrastructure could be located in the Norfolk Boreas Site:

- Between 90 (20MW) and 158 (11.55MW) wind turbines;
- Up to two offshore electrical platforms;
- One offshore service platform;
- Up to two met masts;
- A network of array cables

- Sections of export cables; and
- Interconnector cables or project interconnector cables.

105. The installation of wind turbine foundations and electrical cables has the potential to disturb sediments from: (i) the seabed (surface or shallow near-surface sediments, e.g. from seabed levelling); and (ii) from several tens of metres below the seabed (sub-surface sediments, e.g. from foundation drilling), depending on installation type and method.

106. Section 4.1 shows that up to 44,373,890m^3 of sediment arising from seabed preparation could be disposed of in the Norfolk Boreas site.

6.1.1.1 Changes in suspended sediment concentrations due to foundation installation in the Norfolk Boreas site

107. Foundation installation has the potential to disturb the seabed and shallow near-bed sediments through the dredging required pre-installation and subsequent release of dredged material to the site. In some cases, foundation installation will require drilling activities to be conducted, therefore potentially impacting sub-surface sediments. These impacts are discussed in turn.

6.1.1.1.1 Seabed and shallow near-bed sediments

108. Seabed sediments and shallow near-bed sediments within the Norfolk Boreas site would be disturbed during any levelling or dredging activities to create a suitable base prior to foundation installation.

109. For a sediment release from a single turbine foundation, the worst case scenario is associated with the dredging volume for each 20MW.

110. GBS foundation, with a maximum preparation area of 2,827m^2. This yields a worst-case dredging volume of 14,137m^3 per foundation based on levelling up to 5m of sediment.

111. The worst case total volume for the project is associated with the maximum number (158) of 11.55MW GBS foundations with a maximum preparation area of 1,963m^2. This yields a total dredging volume of 1,648,824m^3. Also, using a worst-case approach the following platforms would be installed:

- Up to two meteorological masts yielding a dredging volume of 12,566m^3;
- Up to two offshore electrical platforms yielding a dredging volume of 75,000m^3; and
- One offshore service platform yielding a dredging volume of 37,500m^3.

112. Therefore, the total maximum seabed preparation volume under the single-phase approach would be 1,773,890m^3 of excavated sediment. The worst case total volume of sediment disturbed as a result of cable installation within the Norfolk Boreas site is estimated to be 42,600,000m^3, this is based on the installation of 600km of array cable, 60km of interconnector cable and 50km of export cable (Table 4.1). The assessment assumes that the sediment would be returned to the water column at the sea surface during disposal from the dredger vessel.

113. This process would cause localised and short-term increases in suspended sediment concentrations both at the point of dredging at the seabed and, more importantly, at the point of its discharge back into the water column.

114. Expert-based assessment suggests that, due to the predominance of medium-grained sand across the Norfolk Boreas site, the sediment disturbed by the drag head of the dredger at the seabed would remain close to the bed and settle back to the bed rapidly. Most of the sediment released at the water surface from the dredger vessel would fall rapidly (minutes or tens of minutes) to the seabed as a highly turbid dynamic plume immediately upon its discharge (within a few tens of metres along the axis of tidal flow).

115. Some of the finer sand fraction from this release and the very small proportion of mud that is present are likely to stay in suspension for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle (up to six hours). Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours). Whilst lower suspended sediment concentrations would extend further from the dredged area, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

116. Due to the predominance of medium-grained sand across The Norfolk Boreas site, the sediment disturbed by the drag head of the dredger at the seabed would remain close to the bed and settle back to the bed rapidly.

117. The conclusions of the assessment on changes in suspended sediment concentrations due to foundation installation in the Norfolk Boreas Site, presented in Chapter 8 Marine Geology, Oceanography and Physical Processes of the ES, are based on the results of modelling simulations undertaken for the East Anglia ONE site using the Delft3D plume model (ABPmer, 2012b). The sediment types across East Anglia ONE (5% gravel, 93% sand and 2% mud) are similar to those across the Norfolk Boreas site (5% gravel, 65-100% sand and 10% mud).

118. Also, Norfolk Boreas and East Anglia ONE are similar distances from the amphidromic point, and therefore the tidal currents and hence sediment dispersion patterns would be similar. Given these similarities, the earlier modelling studies for East Anglia ONE are considered to represent a suitable analogue for verifying the conclusions of the more qualitative expert-based assessment described in ES Chapter 8 Marine Geology, Oceanography and Physical Processes.

119. In the East Anglia ONE modelling studies (ABPmer, 2012b), consecutive daily releases of 22,500m^3 of sediment (mostly medium-grained sand, but also with small proportions of gravel, other sand fractions and mud) were simulated at the water surface at 15 wind turbine locations. The value used in the modelling for sediment release is just over double the release volume predicted for each of the Norfolk Boreas 11.55MW wind turbine foundations (10,436m^3), and so can be used as a conservative analogue to establish the magnitude of effect.

120. The ABPmer (2012b) model predicted that close to the release locations, suspended sediment concentrations would be high (orders of magnitude in excess of natural background levels), but of very short duration (seconds to minutes) as the dynamic plume falls to the seabed. Within the passive plume, suspended sediment concentrations above background levels were low (less than 10mg/l) and within the range of natural variability. Net movement of fine-grained sediment retained within the passive plume was to the north, in accordance with the direction of residual tidal flow. Suspended sediment concentrations were predicted to rapidly return to background levels after cessation of the release into the water column.

121. There would be little additional effect of scaling-up from the modelled 15 foundations to the 158 foundations proposed across Norfolk Boreas because the modelled results show that after completion of installation of a foundation, the suspended sediment concentrations do not persist but rapidly return to background levels. Hence, the release of sediment from one foundation installation would not last for a long enough time to interact with the next installation. This would be the case regardless of the number of foundations that were installed and so the cumulative effects of 15 and 158 installations would be similarly small. Given this finding from the modelled consecutive installation of 15 wind turbine foundations (ABPmer, 2012b), it is expected that effects from installation of 158 foundations across the whole of Norfolk Boreas would be less.

6.1.1.1.2Sub-surface sediments

122. Deeper sub-surface sediments within the site could become disturbed during any drilling activities that may be needed at the location of each piled foundation. Although it is not confirmed that drilling will be required the possibility of drilling must

be considered as a worst case scenario. Up to 50% of turbines may require drilling activities as part of the foundation installation process. It should be noted that should piled foundations which require drilling be used, then the volume of pre-sweeping for GBS foundations described above would be minimised or avoided.

123. The drilling process would result in the production of drill arisings, which would cause localised and short term increases in suspended sediment concentrations at the point of discharge of the drill arisings.

124. The worst case scenario for the total volume of drill arisings released during the construction period would consist of a total of 413,913m^3 in the Norfolk Boreas site (with 50% of turbine foundations plus other platforms requiring drilling). Although the sub-surface sediment release quantities involved under this worst case scenario for drill arisings are considerably lower than those involved in the worst case scenario for the surface and near-bed sediments from pre-sweeping, the sediment types would differ, with a larger proportion of finer materials and therefore it is important to assess the potential impact of drill arisings.

125. The disturbance effects at each structure location are likely to last for no more than a few days of construction activity. Expert-based assessment suggests that the coarser sediment fractions (medium and coarse sands and gravels) and aggregated 'clasts' of finer sediment would settle out of suspension in relatively close proximity to the foundation location, whilst disaggregated finer sediments (fine sands and muds) would be more prone to dispersion across a wider area. Due to the small quantities of sediment release involved, however, these disaggregated finer sediments are likely to be widely and rapidly dispersed, resulting in only low elevations in suspended sediment concentration until they ultimately come to rest on the seabed.

6.1.1.1.3 Assessment of effect magnitude and / or impact significance for a single phase construction

126. The worst case changes in suspended sediment concentrations due to seabed preparation for foundation installation are likely to have the magnitudes of effect shown in Table 6.1.

Table 6.1 Magnitude of effect on suspended sediment concentrations due to foundation installation in the Norfolk Boreas site under the worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	High	Negligible	Negligible	Negligible	Medium
Far-field	Low	Negligible	Negligible	Negligible	Low

*The near-field effects are confined to a small area, likely to be several hundred metres up to a kilometre from each foundation location.

127. The effects on suspended sediment concentrations due to offshore cable installation (including any sand wave levelling) would have **no impact** upon the marine physical processes of the Norfolk Boreas site. This is because the processes are active along the seabed and are not affected by sediment suspended in the water column. The impact of suspended sediment on water quality and benthic receptors is discussed in section 6.1.2 and 6.1.3.

6.1.1.1.4 Assessment of effect magnitude and/or impact significance for a two-phase construction

128. The worst-case release of sediments through seabed preparation would occur over two distinct phases, each lasting up to eight months (rather than a single 20-month period), for the installation of the foundations. Whilst this scenario would mean that the effects are caused in two separate periods, with a longer additive duration of disturbance, this would not materially change the assessment of significance compared with a single-phase approach.

6.1.1.2 Changes in seabed levels due to foundation installation in the Norfolk Boreas site

129. The increases in suspended sediment concentrations associated with the impact discussed in section 6.1.1.1 have the potential to result in changes in seabed levels as the suspended sediment settles on the surrounding seabed potentially raising the seabed level slightly. There would be different settling rates for the different sediment types associated with the seabed and shallow near-bed sediment disturbance and the deeper sub-surface sediment disturbance, so each is discussed in turn.

6.1.1.2.1 Seabed and shallow near-bed sediments

130. Expert-based assessment suggests that the coarser sediment would rapidly (within the order of minutes or tens of minutes) fall to the bed as a highly turbid dynamic plume immediately upon its discharge, forming a deposit ('mound') local to the point of release. Due to the sediment grain sizes observed across the site (predominantly medium sand or coarser, with very little fine sand or muds), a large proportion of the disturbed sediment would behave in this manner.

131. When the medium sand and courser material settle out the resulting mound would be a measurable protrusion from the sea bed (likely order of tens of centimetres to a few metres in height) but would remain highly localised to the release point. The material within the mound would be similar to that on the existing sea bed and therefore there would be no significant change in sediment type. Also, the overall change in elevation of the seabed is small compared to the absolute depth of water (greater than 20m). The change in seabed elevation is within the natural change to the

bed caused by sand waves and sand ridges and hence the blockage effect on physical processes would be negligible.

132. The mound will be mobile and be driven by the physical processes, rather than the physical processes being driven by it. This means that over time the sediment comprising the mound will gradually be re-distributed by the prevailing waves and tidal currents.

133. In addition to the local mounds, the very small proportion of mud present within the sediment would form a passive plume and become more widely dispersed before settling on the seabed. The East Anglia ONE modelling (ABPmer, 2012b) considered seabed level changes resulting from deposition of sediments from the passive plume due to seabed preparation for 15 foundations. This involved a worst-case sediment release of 22,500m^3 per foundation (i.e. around twice the volume considered as the worst case for an individual wind turbine foundation in Norfolk Boreas). The deposited sediment layer across the wider seabed was found to be less than 0.2mm thick in most areas and did not exceed 2mm anywhere. The area of seabed upon which deposition occurred (at these low values) extended a considerable distance from the site boundary (around 50km), but in doing so only covered a very narrow width of seabed (a few hundred metres). This is because the dispersion of the plume followed the axis of tidal flow. The previous assessment also concluded that this deposited sediment has the potential to become re-mobilised and therefore would rapidly become incorporated into the mobile seabed sediment layer, thus further reducing any potential effect.

134. Using the plume modelling studies for East Anglia ONE as part of the expert-based assessment suggests that deposition of sediment from the Norfolk Boreas plume would occur across a wide area of seabed and would be very thin (millimetres). Given that the maximum sediment volume released through seabed preparation would be less than the modelled release at East Anglia ONE; the worst case thickness of sediment deposited from the plume will also be less (given similar hydrodynamic conditions). Hence, it is anticipated that the worst case sediment thicknesses at Norfolk Boreas would not likely exceed a maximum of 1.4mm and be less than 0.14mm over larger areas of the seabed.

135. This expert-based assessment is supported by an evidence-base obtained from research into the physical impacts of marine aggregate dredging on sediment plumes and seabed deposits (Whiteside *et al*., 1995; John *et al*., 2000; Hiscock and Bell, 2004; Newell *et al*., 2004; Tillin *et al*., 2011; Cooper and Brew, 2013).

6.1.1.2.2 Sub-surface sediments

136. Expert-based assessment suggests that due to the finer-grained nature of any sub-surface sediment released into the water column from drilling, there would be greater dispersion across a wider area, in keeping with the pattern of the tidal ellipses.

137. The bed level changes that are anticipated would move across the site with progression of the construction sequence as the point of sediment release (and hence geographic location of the zone of effect) changes with the installation at different locations.

138. A very conservative worst case scenario has also been considered whereby the sediment released from the drilling is assumed to be wholly in the form of aggregated 'clasts' of finer sediment that remain on the sea bed (at least initially), rather than being disaggregated into individual fine-grained sediment components immediately upon release. Under this scenario, the worst case assumes that a 'mound' would reside on the sea bed near the site of its release, in this case surrounding the wind turbine foundations.

139. The maximum footprint of an individual mound arising would be 8,836m^2 from a 20MW monopile turbine foundation.

140. The maximum area of footprint for drilling mounds associated with the whole project would be 441,800m^2 for 45 (50%) of the 20MW monopile foundations, as well as offshore service platform and offshore electrical platforms on six-legged foundations and met masts on quadropods.

6.1.1.2.3Assessment of effect magnitude and/or impact significance for a single-phase construction

141. The models of East Anglia ONE were successfully calibrated and verified with existing data, and so there is high confidence in the assessment of effects, including their scaling up from modelling results of a sub-set of wind turbines to the whole Norfolk Boreas project area.

142. The changes in seabed levels due to foundation installation under the worst case sediment dispersal scenario are likely to have the magnitudes of effect shown in Table 6.2.

Table 6.2 Magnitude of effects on seabed level changes due to sediment deposition following foundation installation under the worst case sediment dispersal scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field[3]	Medium	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

143. It was concluded that the overall impact of foundation installation activities on sea bed levels in the Norfolk Boreas site would be **negligible impact**.

6.1.1.2.4Assessment of effect magnitude and/or impact significance for a two-phase construction

144. Under the two-phase approach, the principal differences compared to the single-phase assessment are those described previously for construction impact 1B (i.e. the effect of distinct construction periods). Consequently, there would be no material change to the assessment of significance for two phases compared with that for a single phase.

6.1.1.3 Changes in suspended sediment concentrations during cable installation in the Norfolk Boreas site

145. The installation of the array, export and interconnector cables has the potential to disturb seabed sediment to a depth of up to 3m. Disturbance could be through levelling of sand waves that may be present along the cables prior to installation or directly through installation of the cable (worst case scenario is jetting) and finally through the disposal of dredged material back onto the site, temporarily increasing sediment concentrations in the water column.

146. Any excavated sediment due to sand wave levelling for the array and interconnector cables would be disposed of within the Norfolk Boreas site. For the worst-case scenario, it is assumed that sand wave levelling may be required for 100% of the array cables, interconnector cables, project interconnector cables or export cables to an average depth of 3m and with an average width of 20m. This equates to a total of 802km of cable, 16km^2 of seabed or excavation of 48,120,000m^3 of sediment, see ES Chapter 8 Marine Geology, Oceanography and Physical Processes for further details.

147. Optimisation of array cable and interconnector cable alignment, depth and installation methods during detailed design would ensure that effects are minimised. The direct impact of change to the substrate elevation is about 2% of the Norfolk Boreas site. In addition, the dynamic nature of the sand waves in this area means that any direct

[3] The near-field effects are confined to a small area of seabed (likely to be several hundred metres up to a kilometre from each foundation location) and would not cover the whole of Norfolk Vanguard.

changes to the seabed associated with sand wave levelling are likely to recover over a short period of time due to natural sand transport pathways.

148. Any excavated sediment due to pre-sweeping for the array and interconnector cables would be disposed of within the Norfolk Boreas site. This means there will be no net loss of sand within the site. It is likely that some of this sand could be disposed on the upstream side of the cable where tidal currents would, over time, re-distribute the sand back over the levelled area (as re-formed sand waves). The overall effect of changes to the seabed would therefore be minimal.

149. Also, in many parts of the Norfolk Boreas site there would not be the need for release of sediment volumes as considered under this worst-case scenario and optimisation of array cable and interconnector cable alignment, depth and installation methods during detailed design would ensure that effects are minimised.

150. The predominance of medium-grained sand (which represents most of the disturbed sediment) means that most of the sediment would settle out of suspension within a few tens of metres along the axis of tidal flow from the point of installation along the cable and persist in the water column for less than a few tens of minutes.

151. Mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected a greater distance and persist in the water column for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle. Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours). Whilst lower suspended sediment concentrations would extend further from the cable, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

6.1.1.3.1Assessment of effect magnitude and / or impact significance for a single-phase installation

152. The worst case changes in suspended sediment concentrations due to array cable and interconnector cable installation (including any necessary sand wave levelling) are likely to have the magnitudes of effect described in Table 6.3.

Table 6.3 Magnitude of effect on suspended sediment concentrations due to cable installation in the Norfolk Boreas site under the worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field* (offshore)	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of seabed (likely to be of the order of several hundred metres up to a kilometre from the cable), and would not cover the entirety of the seabed area within Norfolk Boreas

153. Overall, these effects will have **no impact** on identified receptors associated with the suspended sediment generated by disposal of material due to interconnector and array cable installation in the Norfolk Boreas site.

6.1.1.3.2Assessment of effect magnitude and/or impact significance for a two-phase installation

154. Under the two-phase approach, the principal difference compared to the single-phase assessment is that installation of the cables would occur over two distinct phases, each lasting up to 12 months (rather than a single, up to 24 month period). However, due to the remaining low near-field and negligible far-field magnitude of effect, this would not materially change the assessment of significance compared with a single-phase approach.

6.1.1.4 Changes in seabed levels during cable installation in the Norfolk Boreas site

155. The increases in suspended sediment concentrations associated with the impact described in section 6.1.1.3 have the potential to result in changes in seabed levels as the suspended sediment deposits on the seabed.

156. Expert-based assessment suggests that coarser sediment disturbed during cable installation (including pre-sweeping) would fall rapidly to the seabed (minutes or tens of minutes) as a highly turbid dynamic plume immediately after it is discharged. Deposition of this sediment would form a linear mound (likely to be tens of centimetres high) parallel to the cable as the point of release moves along the excavation. Due to the coarser sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner and be similar in composition to the surrounding seabed. This would mean that there would be no significant change in seabed sediment type.

157. A very small proportion of mud would also be released to form a passive plume and become more widely dispersed before settling on the seabed. Expert-based assessment suggests that due to the dispersion by tidal currents, and subsequent deposition and re-suspension, the deposits across the wider seabed would be very thin (millimetres).

6.1.1.4.1Assessment of effect magnitude and / or impact significance for a single-phase installation

158. Expert-based assessment indicates that changes in suspended sediment concentration due to array, interconnector or project interconnector and export cable installation (including any necessary sand wave levelling) within the Norfolk Boreas site would be minor and are likely to have the magnitudes of effect shown in Table 6.4.

Table 6.4 Magnitude of effect on seabed level changes due to array, interconnector or project interconnector and export cable installation in the Norfolk Boreas site (including sand wave levelling) under the worst case scenario

Location	Scale	Duration	Frequency	Reversibility	Magnitude of Effect
Near-field*	Low	Negligible	Negligible	Negligible	Low
Far-field	Negligible	Negligible	Negligible	Negligible	Negligible

*The near-field effects are confined to a small area of seabed (likely to be of the order of several hundred metres up to a kilometre from the cable) and would not cover the whole of Norfolk Boreas.

159. These effects on seabed level are considered highly unlikely to have the potential to impact directly upon the identified receptor groups for marine physical processes. Any impacts will be of a significantly lower magnitude than those seabed level impacts already considered for the installation of foundations. Consequently, the overall impact of array, interconnector or project interconnector and export cable installation activities within the Norfolk Boreas site under a worst case scenario on seabed level changes for identified morphological receptor groups is therefore considered to be **negligible impact**.

6.1.1.4.2Assessment of effect magnitude and/or impact significance for a two-phase installation

160. Under the two-phase approach, the principal differences compared to the single-phase assessment are those described previously. Consequently, there would be no material change to the assessment of significance compared with that for a single-phase approach.

6.1.1.5 Summary of impacts of sediment disposal on physical characteristics in the Norfolk Boreas site

161. As the conclusion of all relevant impacts on physical characteristics was that there would be negligible impact, it is unlikely that there would be any discernible effect on the physical characteristics of the sites due to the proposed sediment disposal.

6.1.2 Potential Impacts of Sediment Disposal on Water and Sediment Quality in the Norfolk Boreas site

162. Disposal of sediment has the potential to change water quality, either through increased sediment concentrations resulting from the disposal plume or impacts associated with the release of sediment bound contaminants. This is considered in detail in Chapter 9 Marine Water and Sediment Quality of the ES.

163. A summary of the potential impacts to water and sediment quality due to sediment disposal is summarised below.

6.1.2.1 Change in water quality due to re-suspension of sediments in the Norfolk Boreas site

164. Seabed sediments and shallow near-bed sediments within the Norfolk Boreas site would be disturbed during any levelling or dredging activities to create a suitable base prior to the installation of foundations. The worst case scenario assumes that sediment would be dredged and returned to the water column at the sea surface as overflow from a dredging vessel. This process would cause localised and short-term increases in suspended sediment concentrations both at the seabed and at the point of discharge into the water column, however the disturbance effect at each wind turbine location are likely to last for no more than a few days.

165. Sections 6.1.1.1 and 6.1.1.3 outline the volumes of sediment that will be disposed of in Norfolk Boreas site in the worst case scenario of foundations, export, array, interconnector or project interconnector cable installation.

6.1.2.1.1Assessment of effect magnitude and / or impact significance

166. The changes in suspended sediment concentrations due to seabed preparation are predicted to be low in magnitude due to the localised and short term nature of the predicted sediment plumes. Baseline conditions of suspended sediment concentrations are expected to return to normal rapidly following cessation of activity, therefore any impact will only be present during the installation process. The sensitivity in the offshore project area is deemed to be low due to the large volume of the receiving water and the capacity for dilution and flushing and therefore a **minor adverse** impact significance is predicted.

6.1.2.2 Change in water quality in the Norfolk Boreas site due to re-suspension of contaminants within sediment

167. The disposal of dredged material has the potential to release sediment-bound contaminants, such as heavy metals and hydrocarbons, into the water column.

168. The data discussed in section 3.2 of this report shows that the levels of contaminants within the Norfolk Boreas site are very low, with only two marginal exceedances in Cefas Level 1 for Arsenic reported. Therefore, the potential magnitude of the effect is considered negligible.

6.1.2.2.1Assessment of effect magnitude and / or impact significance

169. As a result of the negligible magnitude of effect and low receptor sensitivity, the re-suspension of contaminated sediment from construction activities is considered to be of **negligible** significance.

6.1.2.3 Summary of impacts of sediment disposal on water and sediment quality in the Norfolk Boreas site

170. As the conclusion of all relevant impacts on water and sediment quality was that they would be of minor and negligible significance it is considered that, should the Norfolk Boreas site be designated a disposal site, impacts to water and sediment quality would be of no greater than **minor adverse** significance.

6.1.3 Potential Impacts of Sediment Disposal on Benthic Ecology in the Norfolk Boreas site

171. Chapter 10 Benthic and Intertidal Ecology of the ES provides a detailed assessment of the impacts of the project on benthic habitats and species. Provided below is a summary of the important findings which relate to the disposal of sediment.

6.1.3.1 Increased suspended sediment concentrations

172. Increases in suspended sediment concentrations within the water column has the potential to affect the benthos through blockage to the sensitive filter feeding apparatus of certain species and / or smothering of sessile species upon deposition of the sediment. Changes in turbidity decrease the depth to which natural light can penetrate into the water column and may therefore result in a reduction in primary productivity. Additionally, sediment plumes can create barriers to movement of marine ecological parameters.

173. The worst case scenario would result in 44,373,800m^3 of sediment being disposed of in the Norfolk Boreas site due to seabed preparation and sand wave levelling for the following:

- Foundations;
    - 158 of the foundations (requiring preparation for a circular area with diameter of 50m);
    - Two offshore electrical platforms and one offshore service platform with 7,500m^2 preparation areas each;
    - Up to 40m diameter pre-sweeping for two met masts;

- Cable installation with 20m disturbance width;
    - 50km of export cables;
    - 600km of array cables; and
    - 60km of interconnector or project interconnector cables.

174. As discussed in section 6.1.1.1 the sediment in the Norfolk Boreas site is predominantly medium grain sand with very small percentages of mud and gravel. As a result, this sediment would fall as a highly turbid dynamic plume upon its discharge, reaching the seabed within minutes or tens of minutes and within tens of metres along the axis of tidal flow from the location at which it was released. The resulting mound would be likely to be tens of centimetres to a few metres high. The small proportion of fine sand and mud would stay in suspension for longer and form a passive plume. This plume (tens of mg/l) would be likely to exist for around half a tidal cycle (i.e. approximately 6 hours). Sediment would settle to the seabed within approximately 1km along the axis of tidal flow from the location at which it was released. These deposits would be very thin (millimetres).

175. Additionally, the potential sediments raised from drillings may form clasts on the seabed, however this would be temporary and within the seabed preparation footprint.

6.1.3.1.1Assessment of effect magnitude and / or impact significance

176. The sensitivity of the receptors in Norfolk Boreas to increases in suspended sediments and smothering are shown below in Table 6.5. The majority of receptors are not sensitive to increased suspended sediments and smothering (Tyler-Walters 2004, Lear and Allen, 2004; Tillin et al*.,* 2015; Jackson & Hiscock, 2008; Ager, 2005). *S. spinulosa* and *Spiophanes bombyx* use sediment to build tubes and can therefore thrive in environments with increased suspended sediments. The maximum sensitivity is shown for *S. spinulosa,* where smothering reaches a level at which there is no tolerance, in which case the recoverability would be medium when the deposited sediments disperse resulting in medium sensitivity. The worst case scenario is therefore an impact of **minor adverse** significance.

Table 6.5 Sensitivities of receptors within the Norfolk Boreas site to increased suspended sediment and smothering by deposited sediment (source: Tyler-Walters 2004, Lear and Allen, 2004; Tillin et al., 2015; Jackson & Hiscock, 2008; Ager, 2005)

Receptor	Tolerance	Recoverability	Overall sensitivity
Light smothering – up to 5cm			
Sublittoral sands and muddy sands	Not available		
***S. spinulosa* on stable circalittoral mixed sediment**	High	High	Not sensitive

Receptor	Tolerance	Recoverability	Overall sensitivity
Sabellaria spinulosa	Low	Immediate	Not sensitive
Spiophanes bombyx	Low	High	Low
Abra alba	Low	Immediate	Not sensitive
Polinices Pulchellus	Not available		
Heavy smothering – up to 30cm			
Sublittoral sands and muddy sands	Not available		
***S. spinulosa* on stable circalittoral mixed sediment**	None	Medium	Medium
S. spinulosa	Medium		
S. bombyx	Not available		
A. alba	Not available		
P. Pulchellus	Not available		
Increased Suspended Sediment Concentrations			
Sublittoral sands and muddy sands	Not available		
***S. spinulosa* on stable circalittoral mixed sediment**	High	High	Not sensitive
S. spinulosa	Low	Immediate	Not sensitive
S. bombyx	Tolerant	N/A	Not sensitive
A. alba	Tolerant	N/A	Not sensitive
P. Pulchellus	Not available		

* Based on Natural England's advice during relevant representation for Norfolk Vanguard (see Table 10.2 of ES Chapter 10 Benthic Ecology (document reference 6.1.5).

6.1.3.2 Re-mobilisation of contaminated sediments

177. Given the low level of contaminants present in the sediments within the Norfolk Boreas site (see section 3.2), changes in water and sediment quality throughout the study area due to re-suspension of contaminants during construction have been assessed as minor.

178. Marine Evidence based Sensitivity Assessment (MarESA) (MarLIN, 2017) shows that, where contaminants levels are within environmental protection standards, marine species and habitats are not sensitive to changes that remain within these standards.

179. All construction activities will be covered by a Project Environmental Management Plan (PEMP) as well as emergency plans in the case of an accidental spillage or leak to ensure no release of contaminants as a result of the project. In addition to this, all vessels must adhere to the requirements of the MARPOL Convention Regulations with appropriate preventative and control measures.

6.1.3.2.1Assessment of effect magnitude and / or impact significance

180. As a result of the absence of existing contamination and mitigation to avoid release of contaminants, there would be **no impact** to the benthic or intertidal ecology.

6.1.3.3 Summary of impacts of sediment disposal on benthic ecology in the Norfolk Boreas site

181. As the conclusion of all relevant impacts on benthic ecology was that they would range from no impact to minor adverse significance it is considered that, should the proposed Norfolk Boreas disposal site be designated, impacts would occur to benthic species however these would be no greater than of minor adverse significance.

6.2 Project Interconnector Search Area (HU214, HU215 and HU216)

182. The project interconnector search area is located across three existing disposal sites (site reference HU214, HU215 and HU216, see Figure 1.1) and therefore Norfolk Boreas Limited is applying to dispose of material arising from the installation of project interconnector cables within these three sites. Section 4.1 provides the maximum possible volume of sediment which could be disposed of within each of the sites. It should be noted that the EIA assesses the overall impacts of installing the project interconnector cables within the entire project interconnector search area, rather than the individual disposal sites.

183. The details of the project interconnector cabling are dependent upon the final project design, but present estimates of the maximum length of project interconnector cable trenches[4] would be up to 92km within the project interconnector search area. Of this total, depending on which electrical solution is chosen either:

- A maximum of 60km would be located in the overlap with the offshore cable corridor (HU214) and 20km would be within the overlap with Norfolk Vanguard West (HU216) (Electrical solution (c), or
- A maximum of 92km would be within the overlap with the Norfolk Vanguard East (HU215) (Electrical solution (b).
- In addition to the project interconnector cables sections of export cables would also be installed within HU214 (Table 4.1)

[4] It should be noted that there would only be a requirement for either the interconnector cables or the project interconnector cables but never both. This is secured by Requirement 5(5) in the DCO (Schedule 1, Part 3).

6.2.1 Potential Impacts of Sediment Disposal on Physical Characteristics in the Project Interconnector Search Area

184. Any sediment resulting from pre-sweeping for the project interconnector cables would be disposed of within existing site references HU214, HU215 or HU216. Transport of material dredged from the seabed would be kept to a minimum therefore it is highly likely that the material would be disposed of within the same reference site as it was dredged from.

6.2.1.1 Changes in suspended sediment concentrations and seabed levels during cable installation in the Project Interconnector Search Area

185. Substrate types, as well as sediment transport, wave and tidal processes, are similar to the Norfolk Boreas site. The project interconnector and export cables that could be installed in the project interconnector search area would be the same as the Norfolk Boreas site and therefore the potential impacts on suspended sediment concentrations are as described in section 6.1.1.3 and potential impacts on seabed levels are as described in section 6.1.1.4. Overall, these effects were assessed as having **negligible** or **no impact** on the identified features.

6.2.2 Potential Impacts of Sediment Disposal on Water and Sediment Quality in the Project Interconnector Search Area

186. The disposal of dredged material has the potential to release sediment-bound contaminants, such as heavy metals and hydrocarbons, into the water column.

187. The data discussed in section 3.2 of this report shows that the levels of contaminants within the project interconnector search area are very low, with marginal exceedances of arsenic which are deemed to be from natural sources. Therefore, the potential magnitude of the effect is considered **negligible**.

6.2.3 Potential Impacts of Sediment Disposal on Benthic Ecology in the Project Interconnector Search Area

6.2.3.1 Increased suspended sediment concentrations

188. The sensitivity of the receptors in project interconnector search area to increases in suspended sediments and smothering are shown below in Table 6.6.

189. Most receptors are not sensitive to increased suspended sediments and smothering (Tyler-Walters 2004, Lear and Allen, 2004; Tillin et al., 2015; Jackson & Hiscock, 2008; Ager, 2005, Tillin 2016d). *S. spinulosa* and *S. bombyx* use sediment to build tubes and can therefore thrive in environments with increased suspended sediments. There is no sensitivity assessment available for the *Capitella* genus, however *Capitella Capitata* is commonly found in the UK and has been used as a proxy for the *Capita*

genus. The maximum sensitivity is shown for *S. spinulosa,* where smothering reaches a level at which there is low tolerance, in which case the recoverability would be medium when the deposited sediments disperse resulting in medium sensitivity. The worst case scenario is therefore an impact of **minor adverse** significance.

Table 6.6 Sensitivities of receptors within the project interconnector search area to increased suspended sediment and smothering by deposited sediment (source: Tyler-Walters 2004, Lear and Allen, 2004; Tillin et al., 2015; Jackson & Hiscock, 2008; Ager, 2005, Tillin 2016d)

Receptor	Tolerance	Recoverability	Overall sensitivity
Light smothering – up to 5cm			
Circalittoral coarse sediment	Not available		
***S. spinulosa* on stable circalittoral mixed sediment**	High	High	Not sensitive
Sabellaria spinulosa	Low	Immediate	Not sensitive
Spiophanes bombyx	Low	High	Low
N.Cirrosa	Not available		
Polinice pulchellus	Not available		
Capitella.sp	Low	High	Low
Heavy smothering – up to 30cm			
Circalittoral coarse sediment	Not available		
***S. spinulosa* on stable circalittoral mixed sediment**	None	Medium	Medium
S. spinulosa	Medium *		
S. bombyx	Not available		
Nephtys cirrosa	Not available		
P. Pulchellus	Not available		
Capitella.sp	Low	High	Low
Increased Suspended Sediment Concentrations			
Circalittoral coarse sediment	Not available		
***S. spinulosa* on stable circalittoral mixed sediment**	High	High	Not sensitive
S. spinulosa	Low	Immediate	Not sensitive
S. bombyx	Tolerant	N/A	Not sensitive
N. Cirrosa	Not available		
P. Pulchellus	Not available		
Capitella.sp	Medium	Low	High

* Based on Natural England's advice during relevant representation for Norfolk Vanguard (see Table 10.2 of ES Chapter 10 Benthic Ecology).

6.2.3.2 Re-mobilisation of contaminated sediments

190. Given the low level of contaminants present in the sediments within the project interconnector search area (see section 3.2), changes in water and sediment quality throughout the study area due to re-suspension of contaminants during construction have been assessed as negligible.

191. MarESA (MarLIN, 2017) shows that, where contaminants levels are within environmental protection standards, marine species and habitats are not sensitive to changes that remain within these standards.

192. All construction activities will be covered by a PEMP as well as emergency plans in the case of an accidental spillage or leak to ensure no release of contaminants as a result of the project. In addition to this, all vessels must adhere to the requirements of the MARPOL Convention Regulations with appropriate preventative and control measures.

193. As a result of the absence of existing contamination and mitigation to avoid release of contaminants, there would be **no impact** to the benthic or intertidal ecology.

6.2.3.3 Summary of impacts of sediment disposal on benthic ecology in the project interconnector search area

194. As the conclusion of all relevant impacts on benthic ecology was that they would range from no impact to minor adverse significance it is considered that, should the applicant dispose of sediment within disposal site references HU214, HU215 and HU216, the potential impacts of the project alone on to benthic species would be no greater than **minor adverse** significance.

6.3 Offshore Cable Corridor within the SAC (HU213)

6.3.1 Potential Impacts of Sediment Disposal on Physical Characteristics in HU213

195. A total of four HVDC cables would connect the offshore wind farm to landfall. These cables would be installed in two trenches (two cables per trench), with a maximum total trench length of 80km within HU213. In terms of the worst case scenario the maximum sediment released due to disposal of pre-swept material would be 500,000m^3 (Figure 1.1 and Table 4.1). The 100,000m^3 dredged from the remainder of the offshore cable corridor has been considered within section 6.2.

196. The sediment released at any one time would be subject to the capacity of the dredger(s); however as agreed with Natural England, disposal would be at least 50m from *S.spinulosa* reef identified during pre-construction surveys.

197. Trenching for the offshore export cables would be back filled either naturally or through the use of a trenching tool with no sediment disposal and therefore this is

not discussed further in this report, but is assessed in the ES (document reference 6.1.10 of the Application, APP-223).

6.3.1.1 Potential Impacts of Sediment Disposal on Physical Characteristics in the SAC

198. The southern part of the Haisborough, Hammond and Winterton SAC (within which HU213 is located) is comprised of a series of sand ridges. These sand bank features are a primary reason for the designation of the SAC and the driving mechanisms for the formation and maintenance of these banks includes physical characteristics; tidal currents, waves and sea-level change, whilst sediment transport (supply to/loss from) is also important in enabling growth or decay.

199. As discussed in section 2, Natural England has requested that where pre-sweeping is undertaken within the Haisborough, Hammond and Winterton SAC, any disturbed seabed sediment should be deposited back into the SAC to ensure material is not lost from the system. Norfolk Boreas Limited have made the commitment to comply with Natural England's request.

200. The SAC is designated for two Annex I habitats 'Sand banks slightly covered by sea water all the time' and 'Reefs' formed by *S. spinulosa*. The Conservation Objectives for this SAC are:

- Maintain the Annex I Sand banks in Favourable Condition, implying that existing evidence suggests the feature to be in favourable condition; and
- Maintain or restore the Annex I reefs in Favourable Condition, implying that the feature is degraded to some degree.

201. The Information to Support the HRA (document reference 5.3 of the Application, APP-201) provides an assessment of the potential effects associated with Norfolk Boreas in relation to these conservation objectives.

6.3.1.2 Changes in Suspended Sediment Concentrations during cable installation within HU213;

202. There are similarities in water depth, sediment types and metocean conditions between the offshore cable corridor for Norfolk Boreas and the East Anglia ONE offshore wind farm. Hence, the earlier modelling studies (discussed in section 6.1.1.1) provide a suitable analogue for the present assessments and the sediment would be dispersed in a similar manner.

203. In water depths greater than 20m LAT, peak suspended sediment concentrations would be typically less than 100mg/l, except in the immediate vicinity (a few tens of metres) of the release location.

204. Following cessation of installation activities, any plume would have been fully dispersed as a result of advection and diffusion. Sediment arising from the installation of export cables within HU213 would mainly be advected to the north.

6.3.1.2.1Assessment of effect magnitude and / or impact significance for a single-phase installation

205. The effects on suspended sediment concentrations due to offshore cable installation (including any sand wave levelling) would have **no impact** upon the offshore cable corridor (including within the Haisborough, Hammond and Winterton SAC) for marine physical processes. This is because the receptors are dominated by processes that are active along the seabed and are not affected by sediment suspended in the water column.

6.3.1.2.2Assessment of effect magnitude and/or impact significance for a two-phase installation

206. Under the two-phase approach, the principal difference compared to the single-phase assessment is associated with the installation programme. There is no difference in the worst-case length of cable to be installed.

207. For the two-phase approach, the worst-case installation period for the export cables within the offshore cable corridor would be installation in parallel with other elements of the offshore wind farm. Installation of the cables would occur over two distinct phases, each lasting up to nine months (rather than a single eighteen-month period). However, due to the remaining low near-field and negligible far-field magnitude of effect, the overall assessment of significance remains in keeping with that for a single phase.

208. At the landfall, the only difference would be that the landfall operations would be undertaken as two discrete events rather than a single event. Whilst this would increase the occurrence of disturbance events, there would be less volume disturbed during each event compared to the single-phase approach.

6.3.1.3 Changes in Seabed Levels during cable installation within HU213;

209. The increases in suspended sediment concentrations associated with the impact discussed above (section 6.3.1.2) has the potential to result in changes in seabed levels as the suspended sediment deposit on the seabed.

210. The maximum volume associated with pre-sweeping for the export cable within the SAC is 500,000m^3 within HU213 (Table 4.1)

211. Following pre-sweeping, sediment would be 'disturbed' due to trenching for the export cables. This material would simply be pushed to the side of the trench to be backfilled later and therefore does not form part of this disposal site application[5].

212. The East Anglia ONE plume modelling simulations (ABPmer, 2012b) suggest that sand-sized material (which represents most of the disturbed sediment) would settle out of suspension within less than 1km from the point of installation within the offshore cable corridor and persist in the water column for less than a few tens of minutes. Due to the coarser sediment particle sizes observed across the site (predominantly medium-grained sand), a large proportion of the disturbed sediment would behave in this manner.

213. The footprint and thickness of the disposed sediment would be dependent on the method of placement, the volume of material to be disposed of at any one time, the local water depth and the ambient environmental conditions during disposal. The ABPmer sandwave pre-sweeping assessment (Appendix 7.1 of the Information to Support the HRA, document reference 5.3) concludes that the spoil would be likely to range from 0.05m to 4.2m. Sandwaves within the indicative spoil zone typically have amplitudes of 3 to 6m and wavelengths of about 100m. Therefore, there is already some variation in seabed depths within the disposal area and depending on the deposition characteristics (i.e. location, thickness and extent) the result would likely be within the range already encountered within the indicative spoil zone.

214. The commitment to dispose of the dredged sand within the sandbank system of the SAC enables the sand to become re-established within the local sediment transport system by natural processes and encourages the re-establishment of the bedform features. Appendix 7.1 of the Information to Support the HRA (document reference 5.3 of the Application, APP-201) estimates transport rates for sand within the SAC of between 0.01m^3/m/ hr to 3.4m^3/m/ hr, which are also within the range modelled for the wider region of the Southern North Sea (HR Wallingford, 2012).

6.3.1.3.1Assessment of effect magnitude and / or impact significance for a single-phase installation

215. The East Anglia ONE plume modelling simulations discussed above and the ABPmer pre-sweeping assessment (Appendix 7.1 of the Information to Support the HRA, document reference 5.3) indicates that the changes in seabed elevation would be temporary and within the existing variation in seabed morphology. This means that, given these low magnitude changes in seabed level arising from sediment disposal the

[5] It should be noted that the impacts associated with the disturbance of this material are assessed within the ES.

impact on bed level changes is considered to be of **negligible impact** for offshore cable corridor (including within the SAC).

6.3.1.3.2Assessment of effect magnitude and/or impact significance for a two-phase installation

216. Under the two-phase approach, the principal difference compared to the single-phase assessment is that described above. Consequently, there would be no material change to the assessment of significance for this impact compared to a single-phase approach.

6.3.1.4 Summary of impacts of sediment disposal on physical characteristics in HU213

217. As the disposal of sediment would be local to dredged area there will be no net gain or loss of sediment from disposal site HU213. Therefore, it is considered that there would be no significant effects on the physical characteristics within HU213.

6.3.2 Potential Impacts of Sediment Disposal on Water and Sediment Quality within HU213

218. Disposal of sediment within the offshore cable corridor has the potential to change water quality, either through increased sediment concentrations in the water column or impacts associated with the release of sediment bound contaminants.

6.3.2.1 Change in water quality due to re-suspension of sediments

219. Following disposal of sediment arising from pre-sweeping, coarse sediment would settle rapidly to the seabed. Mud-sized material (which represents only a very small proportion of the disturbed sediment) would be advected a greater distance and persist in the water column for longer and form a passive plume which would become advected by tidal currents. Due to the sediment sizes present, this is likely to exist as a measurable but modest concentration plume (tens of mg/l) for around half a tidal cycle. Sediment would eventually settle to the seabed in proximity to its release (within a few hundred metres up to around a kilometre along the axis of tidal flow) within a short period of time (hours). Whilst lower suspended sediment concentrations would extend further from the cable, along the axis of predominant tidal flows, the magnitudes would be indistinguishable from background levels.

220. The magnitude of the impact is therefore anticipated to be low and, combined with low sensitivity of the receptor, the overall significance is predicted to be **minor adverse**.

6.3.2.2 Change in water quality due to re-suspension of contaminants within sediment

221. Disturbance of seabed sediments has the potential to release any sediment-bound contaminants, such as heavy metals and hydrocarbons, into the water column. The data in section 3.2 indicates the low levels of contaminants in the sediment within the

offshore cable corridor; only one marginal exceedance in Cefas Level 1 for Arsenic is reported.

222. As a result of the low magnitude of effect, the re-suspension of contaminated sediment from construction activities within HU213 is considered to be of **negligible** significance.

6.3.2.3 Summary of impacts of sediment disposal on water and sediment quality in the HU213

223. As the worst case conclusion of all relevant impacts on the physical characteristics of HU213 was **minor adverse** significance, there will be no greater impact on the water and sediment quality within the offshore cable corridor as a result of sediment extraction and subsequent disposal required for the installation of the offshore export cable.

6.3.3 Potential Impacts of Sediment Disposal on Benthic Ecology in HU213

6.3.3.1 Increased suspended sediment concentrations

224. As discussed in previous sections, there are likely to be increases in suspended sediment concentrations in the water column due to activities relating to the export cable installation.

225. Increases in suspended sediment concentrations within the water column has the potential to affect the benthos through blockage to the sensitive filter feeding apparatus of certain species and / or smothering of sessile species upon deposition of the sediment. Changes in turbidity decrease the depth to which natural light can penetrate into the water column and may therefore result in a reduction in primary productivity. Additionally, sediment plumes can create barriers to movement of marine ecological parameters.

6.3.3.1.1Assessment of effect magnitude and / or impact significance

226. The sensitivity of these receptors to increases in suspended sediments and smothering are shown below in Table 6.7. As some areas of potential *S. spinulosa* reef were found within HU213, there is the potential for these areas to be impacted by increased suspended sediment concentrations and smothering. As *S. spinulosa* rely on suspended solids in order to filter feed and build tubes, they are often found in areas of high levels of turbidity and have been found to maintain a cumulative growth rate a few hundred metres from primary aggregate extraction sites (Davies *et al.,* 2009).

Table 6.7 Sensitivities to increased suspended sediment and smothering by deposited sediment (source: Tillin, 2016; Tillin & Marshall, 2015; Tillin, 2016b)

Receptor	Tolerance	Recoverability	Overall sensitivity
Light smothering – up to 5cm			
Circalittoral coarse sediment	Not available		Not sensitive**
Circalittoral mixed sediment	Not available		
***Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel**	Medium	High	Not Sensitive* - Low
***S. spinulosa* on stable circalittoral mixed sediment**	High	High	Not sensitive
***Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand**	Not available		
Heavy smothering – up to 30cm			
Circalittoral coarse sediment	Not available		Not sensitive**
Circalittoral mixed sediment	Not available		
***Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel**	Medium	Medium	Medium
***S. spinulosa* on stable circalittoral mixed sediment**	None	Medium	Medium
***Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand**	Not available		
Increased Suspended Sediment Concentrations			
Circalittoral coarse sediment	Not available		
Circalittoral mixed sediment	Not available		
***Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel**	Medium	High	Low
***S. spinulosa* on stable circalittoral mixed sediment**	High	High	Not sensitive
***Protodorvillea kefersteini* and other polychaetes in impoverished circalittoral mixed gravelly sand**	High	High	Not sensitive*

* based on assessments in Tillin (2014b) which focus on the species which define the biotope

** Based on natural England's advice during relevant representation for Norfolk Vanguard (see Table 10.2 of ES Chapter 10 Benthic Ecology).

227. As shown in Table 6.7, the greatest overall sensitivity of biotopes recorded within the offshore cable corridor to smothering or increased suspended sediment is likely to be medium, with this occurring when between 5cm and 30cm of sediment is deposited on the receptor.

228. In accordance with Table 6.7, a medium sensitivity, and low magnitude of effect for the offshore cable corridor mean that this impact would likely be of **minor adverse** significance. Re-mobilisation of contaminated sediments

229. Given the low level of contaminants present in the sediments within the offshore cable corridor (Table 3.3), changes in water and sediment quality throughout the study area due to re-suspension of contaminants during construction have been assessed as negligible.

230. MarESA (MarLIN, 2017) shows that, where contaminant levels are within environmental protection standards, marine species and habitats are not sensitive to changes that remain within these standards.

231. All construction activities will be covered by a PEMP (as well as emergency plans in the case of an accidental spillage or leak to ensure no release of contaminants as a result of the project. In addition to this, all vessels must adhere to the requirements of the MARPOL Convention Regulations with appropriate preventative and control measures.

6.3.3.1.2Assessment of effect magnitude and / or impact significance

232. As a result of the absence of existing contamination and mitigation to avoid release of contaminants, there would be **no impact** to the benthic or intertidal ecology as a result of disposal within HU213.

6.3.3.2 Summary of impacts of sediment disposal on benthic ecology in HU213

233. The conclusion of the EIA was that relevant impacts on benthic ecology would range from **no impact** to **minor adverse** significance. Therefore it is considered within this assessment that, although impacts to benthic ecology could occur within HU213, these would also be no greater than minor adverse significance.

6.4 Cumulative Impacts

234. Given that only minor impacts are predicted within the Norfolk Boreas site (the proposed Norfolk Boreas disposal site), project interconnector search area (which is within HU214, HU215 and HU216), and the section of the offshore cable corridor within the SAC (which is HU213), there are not predicted to be any cumulative effects between each of the project areas associated disposal activities.

235. Consideration is given in ES Chapters 8, 9 and 10 to potential cumulative effects on the seabed (and therefore on the marine physical processes, water and sediment quality and benthic ecology) associated with other plans and projects. Those of relevance to sediment disposal are:

- Installation of foundation structures for Norfolk Boreas and installation of the East Anglia THREE and Norfolk Vanguard projects;
- Installation of the offshore export cables and project interconnector cables for Norfolk Boreas and offshore export cables for Norfolk Vanguard; and

- Installation of the offshore export cable for Norfolk Boreas and marine aggregate dredging activities in adjacent areas of the seabed.
- As the Applicant is applying to dispose of material within existing disposal sites which have been designated for Norfolk Vanguard, the cumulative impacts associated with that project are of particular relevance. Table 6.8 illustrates the maximum (worst case) combined volume of material that could be disposed of within any of the existing disposal sites if both projects proceed to construction.
- It is important to note that the figures provided in Table 6.8 represent the absolute maximum volumes which could be disposed of within each individual disposal site. This will depend on which electrical solution is chosen and how the Norfolk Vanguard array is distributed between NV East and NV West. For example, if 50,029,712m^3 of material were to be disposed of within HU216 by a combination of Norfolk Boreas and Norfolk Vanguard (as shown in bottom line of Table 6.8) no material would then be disposed of within HU215.
- The maximum disposal quantities across the entire Norfolk Boreas and Norfolk Vanguard projects are secured within the respective Norfolk Boreas draft DCO and the Norfolk Vanguard DCO. Further explanation of the maximum quantities of disposed material secured within the Norfolk Boreas DCO is provided within the reconciliation document (document reference 6.7 of the Application, APP-689).
- Under Scenario 2 (see section 1.2) Norfolk Vanguard would not be proceeding to construction; accordingly, neither Norfolk Boreas nor Norfolk Vanguard would dispose of any material within HU215 or HU216. There would, therefore, be no impact in these areas.

Table 6.8 Maximum combined disposal volumes as a result of Norfolk Boreas and Norfolk Vanguard projects

Existing disposal Site	Disposal Volume by Norfolk Vanguard (m^3)	Disposal Volume by Norfolk Boreas (m^3)	Cumulative disposal Volume (m^3)
HU213	500,000	500,000	1,000,000
HU214	100,000	3,700,000	3,800,000
HU215	48,829,712*	5,520,000	54,349,712
HU216	48,829,712*	1,200,000	50,029,712

* As secured within the Norfolk Vanguard draft Development Consent Order (Norfolk Vanguard Limited, 2019a) this is the maximum volume that could be disposed of by the Norfolk Vanguard project. Up to this value could be disposed of within either site but the combined disposal across the two sites could not exceed this value.

6.4.1 Cumulative Impacts on Physical Characteristics as a Result of Adjacent Wind Farms

236. The impacts of the foundation and offshore cable installation activities were identified to be of negligible impact for Norfolk Boreas alone.

237. The construction programmes of Norfolk Boreas, East Anglia THREE, and/or Norfolk Vanguard may overlap depending on the final construction programmes. The Norfolk Boreas cable corridor and its landfall would be common to the Norfolk Vanguard project and so there is potential for cumulative impacts to arise during construction.

238. The worst case scenario from a marine physical processes perspective would be for all projects to be constructed at the same time. This would provide the greatest opportunity for interaction of sediment plumes and a larger change in seabed level during their construction. The combined change in seabed level sediment plume from foundation and cable installation could have a greater spatial extent and be greater in a vertical sense than each individual project.

239. Table 6.8 provides the maximum combined volume of material to be disposed of within existing disposal sites HU213, HU214, HU215 and HU216 as a result of both Norfolk Vanguard and Norfolk Boreas projects. As the East Anglia THREE project has its own designated disposal site, HU212, there would be no spatial overlap in disposal with that project.

240. As has been concluded for Norfolk Boreas alone, the majority of suspended sediment arising from Norfolk Vanguard and East Anglia THREE would fall rapidly to the seabed after the start of construction and therefore the potential cumulative impact would be of negligible magnitude. The receptor sensitivity would also be negligible and therefore it is considered that the cumulative impact of two or three projects constructing in this area at the same time would be **negligible.**

6.4.2 Cumulative Impacts on Physical Characteristics as a Result of Marine Aggregate Dredging

241. As shown in Figure 18.3 of the Norfolk Boreas ES (document reference 6.2.18.3 of the Application, APP-415) there are no marine aggregate sites in the vicinity of the Norfolk Boreas site (proposed Norfolk Boreas disposal site) or the project interconnector search area (located within existing disposal sites HU214, HU215 and HU216). Therefore, cumulative impacts would only occur within the western parts of the offshore cable corridor (where sediment is disposed of within HU213).

242. In order to assess the potential for cumulative effects between the installation of the offshore cables and marine aggregate dredging activities in adjacent areas of the seabed, reference in the Norfolk Boreas EIA has been made to the EIA for the East Anglia ONE project. Although the cable corridor location is different, the results in relation to physical processes provide a useful and appropriate analogy for Norfolk Boreas.

243. The East Anglia ONE EIA was supported by numerical modelling, using Delft3D plume modelling software, of the potential for interactions of sediment plumes arising from offshore cable installation with those arising from marine aggregate dredging sites (and indeed other seabed activities) located within one spring tidal excursion distance from the East Anglia ONE offshore cable corridor. The modelling showed that some interaction could potentially occur between dredging plumes and plumes from cable installation and that the spatial extent of the combined plume is slightly greater than for the plumes originating from the offshore cable installation only. Whilst maximum plume concentrations would be no greater under the cumulative scenario, a larger geographical area might experience increases in suspended sediment concentrations than for the offshore cable installation only scenario. Following cessation of cable burial and aggregate dredging activities, a few hundred metres away from the immediate release locations maximum theoretical bed level changes of up to 2mm were identified by the model, with maximum levels of around 0.8mm at greater distances.

244. The nearest aggregate extraction site (North Cross Sands) is located over 5km from the part of the Norfolk Boreas offshore cable corridor which is within HU213. Considering the results from East Anglia ONE described above, the potential cumulative impacts between offshore cable installation for Norfolk Boreas and nearby marine aggregate dredging activities would be **negligible** as a conservative estimate.

6.4.3 Cumulative Impacts on Marine Water and Sediment Quality as a Result of Adjacent Wind Farms

245. As described above, the short duration of sediment disturbance anticipated during these installation activities means that changes in water quality due to sediment plumes would be temporary and short term.

246. As a result, it is considered that the cumulative impact for two or three projects would not increase the impact significance predicted as a result of construction of Norfolk Boreas alone (i.e. either **minor adverse** or **negligible** impact significance). Therefore, no cumulative impacts are predicted to occur in either the existing disposal sites (HU213, HU214, HU215 and HU216) or the Norfolk Boreas proposed Norfolk Boreas disposal site.

6.4.4 Cumulative Impacts on Marine Water and Sediment Quality as a Result of Marine Aggregate Dredging

247. The maximum plume concentrations associated with Norfolk Boreas and Marine Aggregate dredging would be no greater overall (as shown by modelling for the East

Anglia ONE EIA) and therefore the cumulative impact magnitude would be low. As Norfolk Boreas is located over 5km from the nearest aggregate extraction site the potential risk of plumes overlapping would be less than assessed for East Anglia ONE.

248. As a result, it is considered that the potential cumulative impacts would be of low magnitude within HU213 and there would be no cumulative impact within HU214, HU215 and HU216 and the proposed Norfolk Boreas disposal site. The sensitivity of the water quality has been assessed as low and therefore an overall impact significance of **minor adverse** is predicted for HU213.

6.4.5 Cumulative Impacts on Benthic Ecology as a Result of Suspended Sediment Concentrations and Associated Sediment Deposition

6.4.5.1 The proposed Norfolk Boreas disposal site

249. As there is no physical overlap with the proposed Norfolk Boreas disposal site and other projects, the potential cumulative impacts on benthic ecology are limited to those associated with increased suspended sediment from the adjacent Norfolk Vanguard and East Anglia THREE projects.

250. There is potential for the construction phase of Norfolk Boreas to overlap with Norfolk Vanguard and East Anglia THREE. The majority of suspended sediment from Norfolk Boreas is expected to settle to the seabed within tens of metres of the source location and the small proportion of fine sand and mud would settle to the seabed within approximately 1km forming a very thin deposit (millimetres) with the sediment travelling with the tidal flow. The East Anglia THREE EIA (EATL, 2015) and Norfolk Vanguard EIA (Norfolk Vanguard Limited, 2018) provide similar estimates and it is assumed that the Norfolk Boreas impacts will be comparable. Cumulative impacts would only occur if sediment is disposed of at locations on the edge of each wind farm, within range of potential overlap of sediment deposition. This scenario is unlikely to occur and as the cumulative impact of deposition would only be millimetres in sediment depth the cumulative impact would be **negligible** at these edge locations, with **no impact** for the majority of locations within the proposed Norfolk Boreas disposal site.

6.4.5.2 Existing disposal sites HU213, HU214, HU215 and HU216

251. As Norfolk Boreas is applying to dispose of sediment within existing disposal sites that have been designated for Norfolk Vanguard there is potential for cumulative impacts to occur to benthic ecology as a result the Norfolk Vanguard project. Due to its proximity, East Anglia THREE must also be considered as part of the cumulative assessment. As discussed above the worst case scenario would be an overlap of construction programmes between East Anglia THREE, Norfolk Vanguard and Norfolk Boreas. As discussed in section 6.4.1 sediment bought into suspension during

construction activities would rapidly fall back to the seabed and therefore it is highly unlikely increased suspended sediment arising from the construction of East Anglia THREE would contribute to the cumulative impact upon existing disposal site HU213, HU214,HU215 and HU216. The Norfolk Boreas cumulative impacts on benthic ecology were assessed as being no worse than minor adverse significance (document reference 6.1.10 of the Application, APP- 223).

252. Table 6.8 illustrates the maximum quantity of sediment that could be disposed of within the existing disposal sites as a result of the construction of both Norfolk Vanguard and Norfolk Boreas. It is highly unlikely that there would be any spatial overlap between seabed levelling and disposal for Norfolk Vanguard and that undertaken for Norfolk Boreas due to the requirement to avoid installed cables including buffer zones. Furthermore, the current combined construction programmes for the two projects show that there is unlikely to be any temporal overlap of dredging and disposal activities within project interconnector search area and therefore HU215 and HU216. There is therefore limited potential for cumulative impacts to occur.

253. The Norfolk Vanguard EIA and site characterisation report (Norfolk Vanguard Limited, 2019b) also concluded that there would be, at worst, impacts of minor adverse significance to benthic ecology within NV East (HU215) and NV West (HU216) (Norfolk Vanguard Limited, 2019b). This was based on a worst case scenario of a volume of 50,607,566m^3 of material being disposed of in each site. A change in the design envelope for foundations to be used for the Norfolk Vanguard project has since reduced the amount of seabed levelling required. This has resulted in the maximum volume of seabed material that could be disposed of within HU216 as a result of the combined Norfolk Boreas and Norfolk Vanguard projects being less than what was originally assessed for Norfolk Vanguard (Table 6.8). The combined maximum volume of material that could be disposed of within HU215 (by both Norfolk Vanguard and Norfolk Boreas) is greater than that originally assessed for the Norfolk Vanguard project alone (Table 6.8) however that increase is less than 8% from what was originally assessed and therefore would not alter the conclusions of the assessment.

254. As concluded in the Norfolk Boreas EIA, cumulative impacts on benthic ecology within the project interconnector search area (covered by HU214, HU215 and HU216) is assessed as being of **minor adverse** significance.

255. The maximum combined disposal volumes for HU213 and HU214 are far smaller than those of HU215 and HU216. Therefore, the magnitude of impact would also be less but would still fall into the low category. The sensitivity of benthic ecology within these sites has been assessed as low (section 6.3.2) and medium (section

6.3.3). Therefore, as concluded in the cumulative impacts on benthic ecology within the Norfolk Boreas ES Chapter 10 (document reference 6.1.10 of the Application, APP-223), impacts within the offshore cable corridor and therefore existing sites HU213 and HU214 would be of **minor adverse** significance. It should also be noted that in the Information to support HRA (document reference 5.3 of the Application APP-201) a conclusion of no adverse effects on Integrity within the Haisborough, Hammond and Winterton SAC is reached for all effects associated with the Norfolk Boreas project. Disposal site HU213 is wholly located within the SAC and this conclusion therefore applies to the disposal site HU213.

6.4.6 Cumulative Impacts on Benthic Ecology as a Result of Marine Aggregate Dredging

256. As discussed above, theoretical bed level changes of up to 2mm are estimated as a result of cumulative impacts from the Norfolk Boreas cable installation and dredging at nearby aggregate sites. The sensitivity of benthic receptors to this level of change would be as described in section 6.3 and the magnitude of this level of change is negligible and therefore the cumulative impact significance will be **negligible.**

7 SUMMARY

257. As part of the DCO application for the proposed Norfolk Boreas project, Norfolk Boreas Limited is applying to: designate a new disposal site to cover the Norfolk Boreas site; and to dispose of material arising from the project interconnector search area and a section of the offshore cable corridor within existing disposal sites which have been designated for use by the Norfolk Vanguard Offshore Wind Farm project. This would allow Norfolk Boreas Limited to dispose of material extracted during construction drilling and seabed preparation (dredging) for associated cable and foundation works. The sea bed sediments in each disposal site are predominantly sand.

258. The following alternative disposal options have been considered for the disposal of drilled and dredged material:

- Use of the material for ballast for certain foundation types;
- Use of material for coastal defence; and
- Use of other existing disposal sites.

259. Worst case scenarios for maximum quantities of material which would need to be excavated for foundations and cable pre-sweeping are provided along with maximum quantities of material released should piled foundations be utilised.

260. The results show that the sediment deposited following pre-sweeping would remain of a similar nature to the adjacent ambient sea bed sediments. Consequently, any subsequent transport would occur at the same time and in the same manner as the ambient sea bed sediments.

261. Release of sediment within the Norfolk Boreas site (and therefore the proposed Norfolk Boreas disposal site) would result in finer grained material associated with the passive plume phase deposited over a wide area with a deposited sediment layer predicted of less than <0.2mm thick. Under the prevailing hydrodynamic conditions, this material would be readily re-mobilised and would therefore quickly be incorporated into the mobile surficial sea bed sediment layer.

262. The footprint and thickness of the sediment deposited in the offshore cable corridor would be dependent on the method of placement, the volume disposed of at any one time, the local water depth and the ambient environmental conditions during disposal. The spoil height is likely to be within the range of seabed morphology already encountered within the indicative spoil zone. The deposited sediment would then be incorporated back into the natural sediment transport processes.

263. Sand sized material from drilling (which would only occur within the proposed Norfolk Boreas disposal site) would settle out of suspension within 1km of the release location and persist in the water column for no more than tens of minutes. Once this material has settled to the sea bed, it would quickly be incorporated into the natural mobile bed regime.

264. Effects from any one foundation installation are unlikely to persist long enough in the same locality to significantly interact with subsequent operations and so no cumulative effects are expected.

265. No significant changes in water quality as a result of sediment contaminant release are expected due to the low levels of existing contaminants and therefore, no resultant impacts on the benthic fauna are predicted.

266. The marine fauna present within the proposed Norfolk Boreas disposal site and existing disposal sites which are proposed for use by Norfolk Boreas Limited are largely tolerant of the increases in sediment suspension and deposition predicted and therefore would not be significantly impacted by the proposed designation of, and additional use of existing disposal sites.

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APPENDIX 1 PROPOSED NORFOLK BOREAS DISPOSAL SITE COORDINATES

Coordinates are all provided in WGS84 Decimal Degrees format

Proposed Norfolk Boreas disposal site				Area excluded from disposal site as not part for the Area in the Agreement for lease			
2.737245	52.866718	2.746916	52.894949	2.985284	53.179596	2.985049	53.175108
2.737261	52.87929	2.747376	52.895299	2.985049	53.1796	2.985284	53.175112
2.737262	52.880201	2.747845	52.895644	2.984814	53.179596	2.984814	53.175112
2.737266	52.880201	2.748324	52.895984	2.98458	53.179583	2.985518	53.175125
2.737338	52.880646	2.748811	52.89632	2.984348	53.179561	2.98575	53.175147
2.737421	52.88109	2.749307	52.896651	2.984119	53.17953	2.985979	53.175178
2.737516	52.881533	2.749811	52.896977	2.983894	53.17949	2.986204	53.175218
2.737623	52.881975	2.750325	52.897299	2.983672	53.179443	2.986425	53.175265
2.737742	52.882416	2.750846	52.897615	2.983457	53.179387	2.986641	53.175321
2.737872	52.882855	2.751376	52.897926	2.983248	53.179323	2.98685	53.175385
2.738014	52.883294	2.751914	52.898232	2.983045	53.179251	2.987052	53.175457
2.738167	52.883731	2.75246	52.898533	2.982851	53.179171	2.987247	53.175537
2.738332	52.884166	2.753014	52.898829	2.982666	53.179085	2.987432	53.175623
2.738509	52.8846	2.753576	52.899119	2.982489	53.178992	2.987608	53.175716
2.738696	52.885032	2.754145	52.899403	2.982323	53.178892	2.987775	53.175816
2.738896	52.885462	2.754722	52.899682	2.982168	53.178786	2.98793	53.175922
2.739106	52.88589	2.755306	52.899956	2.982024	53.178674	2.988074	53.176034
2.739328	52.886316	2.755897	52.900224	2.981892	53.178558	2.988206	53.17615
2.739561	52.88674	2.756496	52.900486	2.981772	53.178436	2.988325	53.176272
2.739805	52.887162	2.757101	52.900742	2.981666	53.17831	2.988432	53.176397
2.74006	52.887581	2.757712	52.900993	2.981572	53.178181	2.988525	53.176527
2.740326	52.887998	2.758331	52.901237	2.981493	53.178048	2.988605	53.17666
2.740604	52.888412	2.758955	52.901476	2.981427	53.177913	2.988671	53.176795
2.740892	52.888823	2.759582	52.901707	2.981376	53.177775	2.988722	53.176933
2.741191	52.889231	2.759586	52.901708	2.981339	53.177635	2.988759	53.177072
2.741501	52.889637	2.75991	53.062782	2.981317	53.177495	2.988781	53.177213
2.741821	52.890039	2.810675	53.141047	2.98131	53.177354	2.988788	53.177354
2.742152	52.890439	3.034321	53.231259	2.981317	53.177213	2.988781	53.177495
2.742493	52.890835	3.035314	53.231658	2.981339	53.177072	2.988759	53.177635
2.742845	52.891228	3.039289	53.233253	2.981376	53.176933	2.988722	53.177775
2.743208	52.891617	3.045347	53.235684	2.981427	53.176795	2.988671	53.177913
2.74358	52.892003	3.05352	53.239183	2.981493	53.17666	2.988605	53.178048
2.743963	52.892385	3.058682	53.24133	2.981573	53.176527	2.988526	53.178181
2.744355	52.892763	3.144725	52.937489	2.981666	53.176397	2.988432	53.17831
2.744758	52.893138	2.97096	52.907509	2.981773	53.176272	2.988326	53.178436
2.74517	52.893508	2.863809	52.888874	2.981892	53.17615	2.988206	53.178558
2.745592	52.893875	2.774386	52.873237	2.982024	53.176034	2.988074	53.178674
2.746024	52.894237	2.759524	52.87063	2.982168	53.175922	2.98793	53.178786
2.746465	52.894595			2.982323	53.175816	2.987775	53.178892
				2.98249	53.175716	2.987609	53.178992
				2.982666	53.175623	2.987432	53.179085
				2.982851	53.175537	2.987247	53.179171
				2.983046	53.175457	2.987053	53.179251
				2.983248	53.175385	2.98685	53.179323
				2.983457	53.175321	2.986641	53.179387
				2.983673	53.175265	2.986426	53.179443
				2.983894	53.175218	2.986204	53.17949
				2.984119	53.175178	2.985979	53.17953
				2.984348	53.175147	2.98575	53.179561
				2.98458	53.175125	2.985518	53.179583